ENGINEERING
LIBRARY

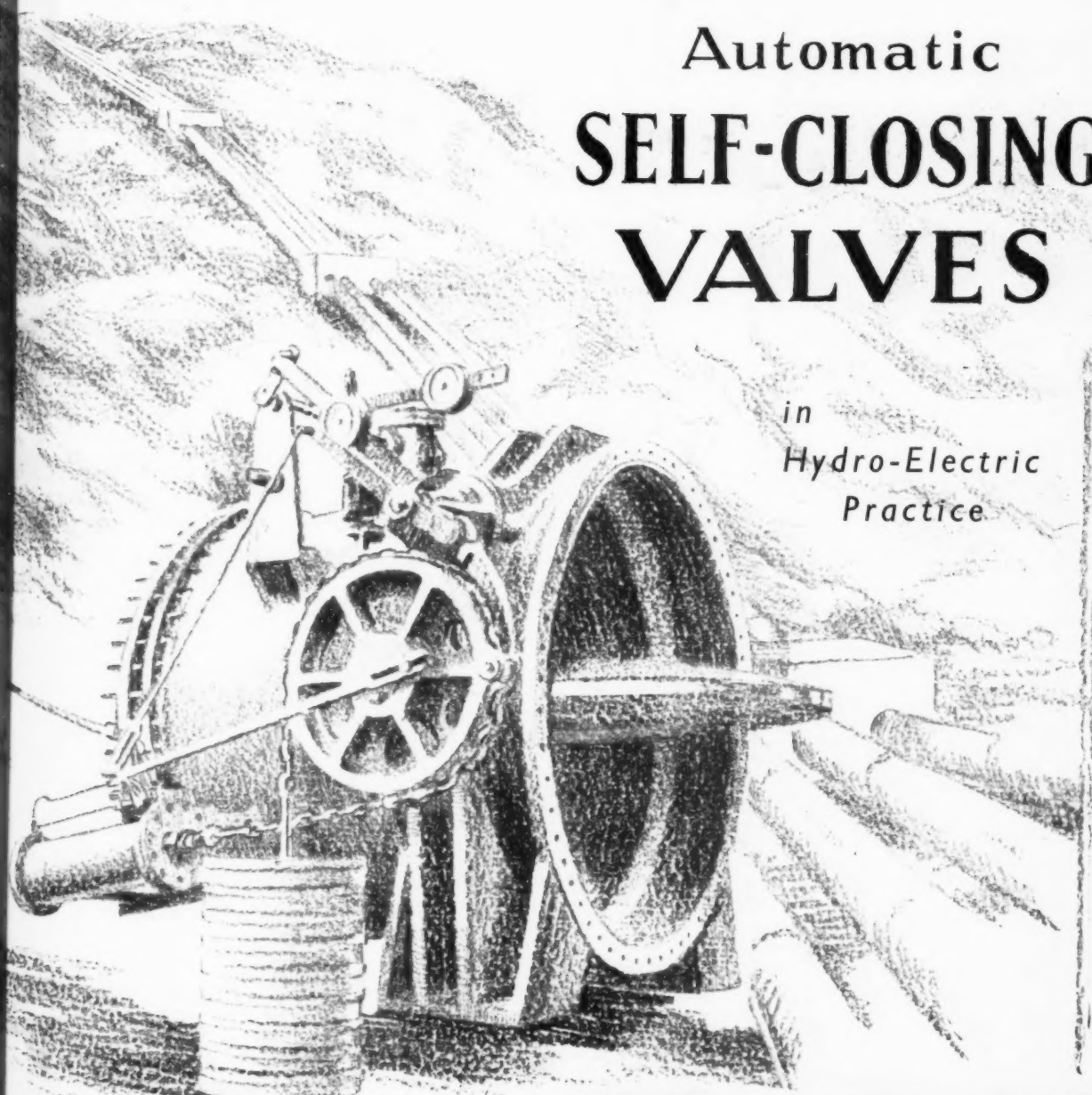
MAY 26 1950

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

MAY-JUNE, 1950

Automatic
SELF-CLOSING
VALVES
in
Hydro-Electric
Practice



Glenfield
GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Coming-of-age

INCORPORATED IN REYROLLE SWITCH-GEAR ARE 21 YEARS OF SHORT-CIRCUIT TESTING AND A LIFE-TIME OF RESEARCH AND EXPERIENCE.

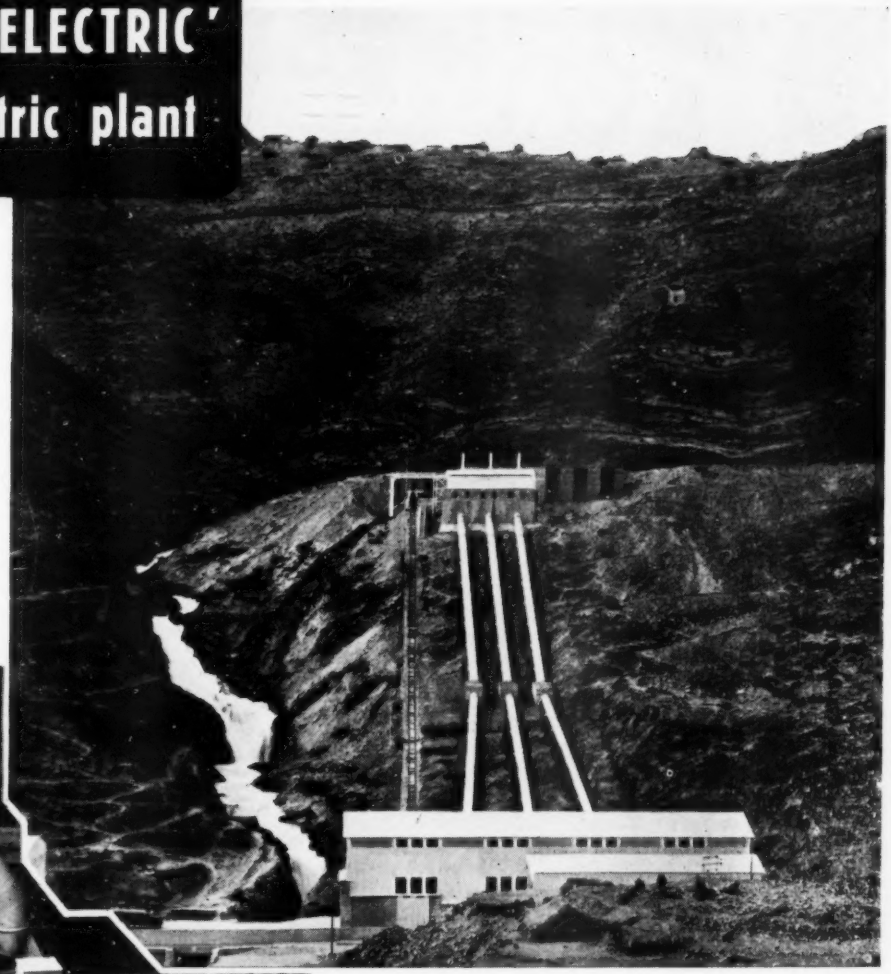
THE KEY TO GUARANTEED SHORT-CIRCUIT PERFORMANCE

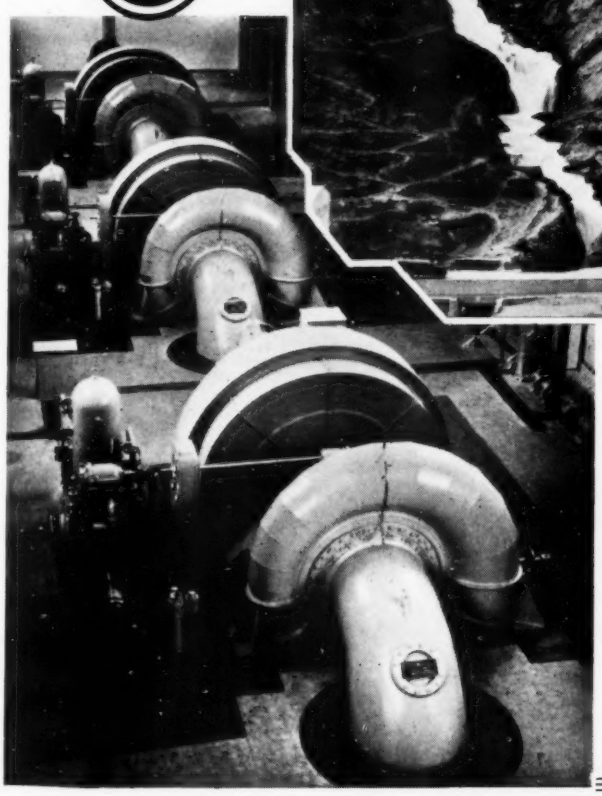
REYROLLE

HEBBURN Co DURHAM ENGLAND

'ENGLISH ELECTRIC' hydro-electric plant

- TURBINES
- GOVERNORS
- VALVES
- GENERATORS
- SWITCHGEAR
- TRANSFORMERS





The Malakand Power Station, in the North West Frontier Province, Pakistan, contains three "English Electric" 4,500 h.p. horizontal reaction water-turbines running under a head of 243 ft. The turbines drive three 3,200 kW 3-phase alternators also of "English Electric" manufacture.

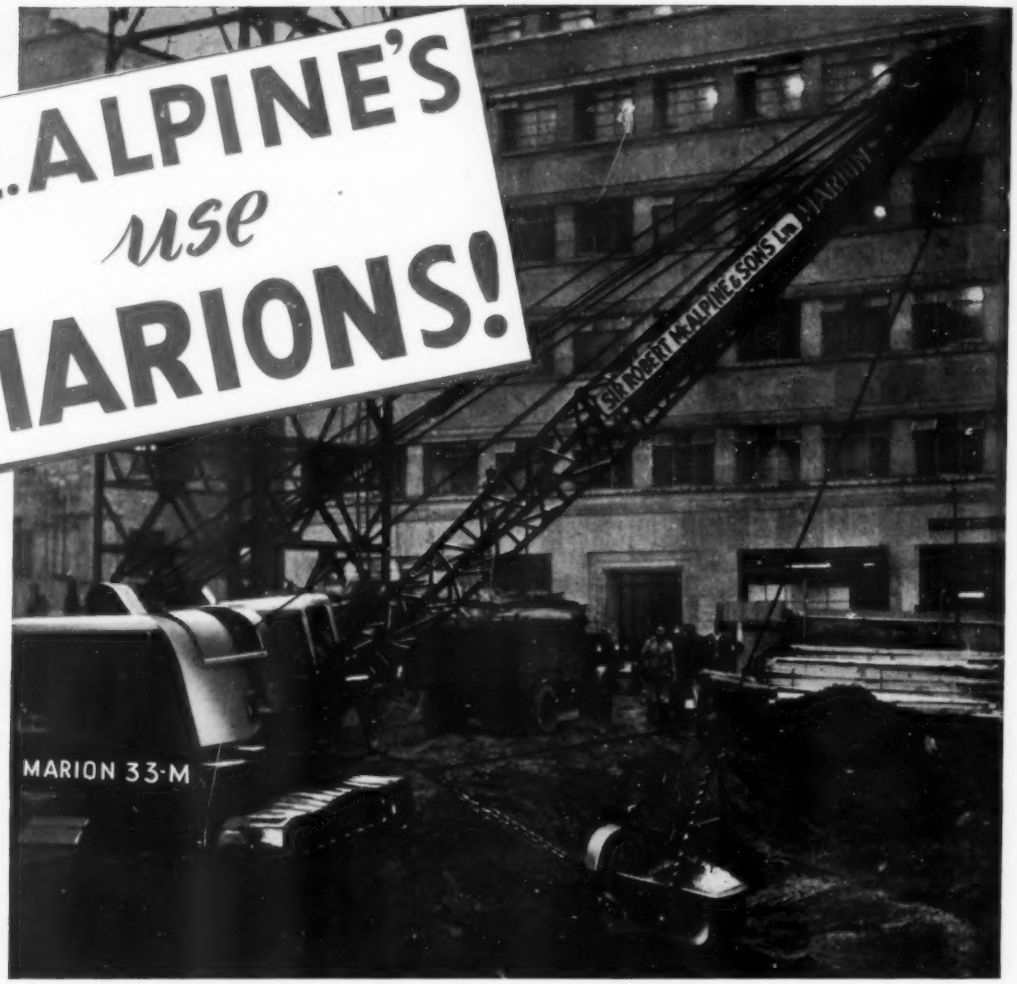
A contract for two further generating sets of the same type, but of 5,000 kW capacity, is now in hand.

The ENGLISH ELECTRIC Company Ltd.

Registered Office: QUEENS HOUSE, KINGSWAY, LONDON, W.C.2.

Works: **STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL**

Mc.ALPINE'S *use* MARIONS!



Messrs. Sir Robert McAlpine & Sons Ltd., used one of their fleet of 40 Marion ¾ cubic yard Draglines—for the removal of 8,000 yards of material on the site of a 90-feet high Office Block to be erected in Savile Row, W.1., by next October.

The Marion 33-M—the smallest model in a most comprehensive range—features light, accurate AIR CONTROLS ; DIESEL POWER ; STURDY CONSTRUCTION, and EASE OF CONVERSION—only two booms being necessary for any type of front-end equipment.

MARION EXCAVATORS from ¾ — 45 CU. YDS.

with a complete After Sales Service by

JOHN BLACKWOOD HODGE & Co. LTD

Sales :
11, BERKELEY STREET, LONDON, W.1.
Telephone : Mayfair 9514.

Works & Service :
HUNSBURY, NORTHAMPTON.
Telephone : Northampton 52623

EIRE, U.S.A., PORTUGAL, SPAIN, SOUTH AFRICA, EAST AFRICA, WEST AFRICA, N. & S. RHODESIA, BELGIAN CONGO, INDIA, PAKISTAN, CEYLON, BURMA, AUSTRALIA.

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Subscription Rates: 20s. Annually Post Free. Single Copies 4s.

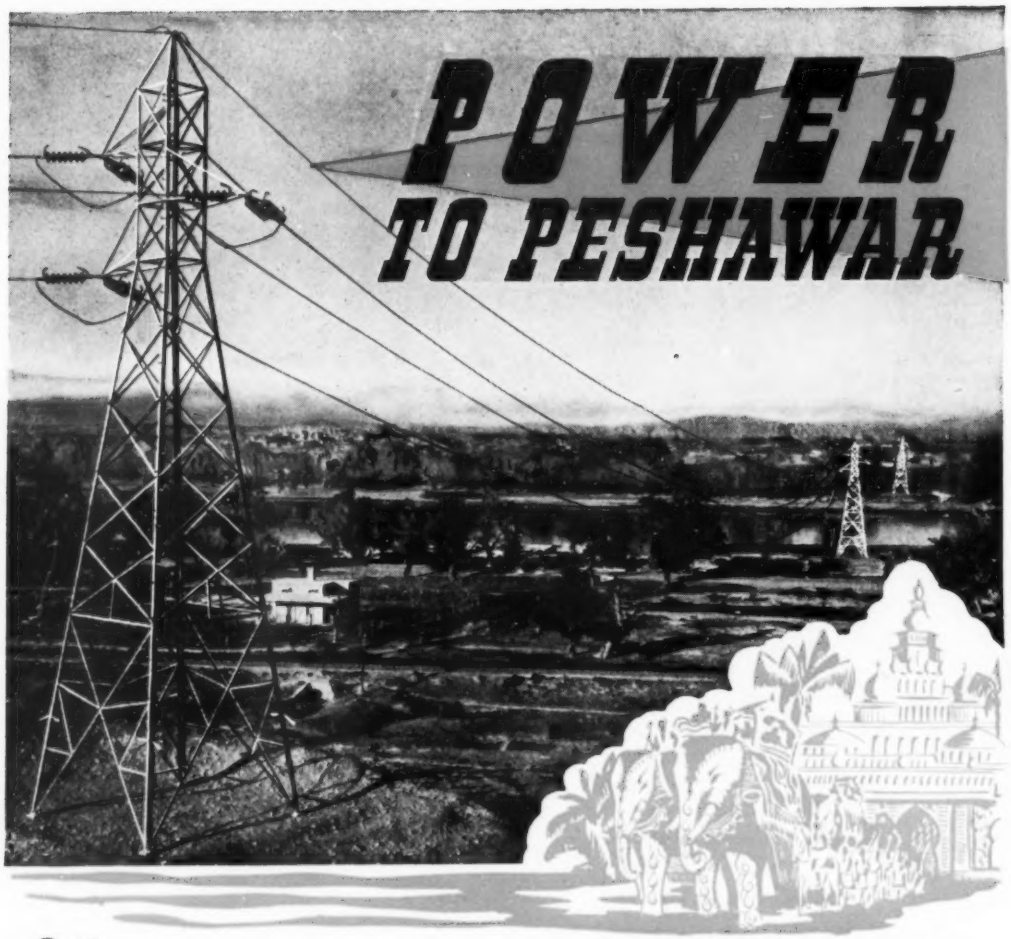
VOLUME 2. NUMBER 3.

CONTENTS FOR MAY—JUNE 1950

Leading Article: Weather - - - - - - - - 89
Editorial Notes - - - - - - - - - - 90
The Zezere Hydro-Electric Scheme - - - - - 93
Particulars of the Castelo do Bode Scheme are given in this article
Loch Sloy - - - - - - - - - - 100
This, the largest power station in the Highlands is now contributing current to the grid
Clunie Power Station - - - - - - - - - 102
The second article on this scheme deals with the generating equipment and electrical distribution
Performance of Francis Turbines - - - - - 108
By Professor Dr. Ing. Igino Tessari
Aerofoil Theory Applied to Kaplan Blades - - - 111
Water Power in Austria - - - - - - - - 112
By Dipl. Ing. Robert Steiner
Hydro-Electric Projects in Greece - - - - - 116
Developments in Canada - - - - - - - - 117
Progress Report, 1949
Hydro-Electric Developments in Iceland - - - - 123
Some Notes on Tunnelling Equipment - - - - 126
Gold Coast Rivers - - - - - - - - - 129
Earth Moving Equipment - - - - - - - 130
From the Journals - - - - - - - - - 131
Contractors' Notes - - - - - - - - - 132

Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

NEWCASTLE-ON-TYNE: 4 Royal Arcade, Pilgrim Street. Telephone: Newcastle 22239.
MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 81 Edmund Street. Telephone: Central 3049.
GLASGOW: 87 Union Street. Telephone: Central 4646.
LEEDS: 70 Albion Street. Telephone 27174



Water from a tributary of the River Indus provides power for the Malakand hydro-electric station, high in Pakistan's North West Frontier Province.

To bring current down to Peshawar and its neighbouring districts, BICC erected over a hundred miles of 66 kV single and double circuit overhead power transmission lines for the Public Works Department.

The grid system crosses rivers, railways and difficult mountain country. It was surveyed and planned by BICC technicians, who also installed the transmission equipment designed and manufactured in the Company's own factories in the U.K.

Wherever the need for high voltage transmission, advantage should be taken of the experience and vast manufacturing resources of the BICC world wide organisation.

B.I. Callender's **OVERHEAD TRANSMISSION**

BRITISH INSULATED CALLENDER'S CABLES LIMITED
NORFOLK HOUSE, NORFOLK STREET, LONDON, W.C.2

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Weather

SPECIAL study is being made of the tremendous floods which rose almost to record proportions during March in the area about the Victoria Falls, Central Africa. Spray from the storm waters of the Zambesi River, pouring over the falls at six to eight knots—or approximately three times the normal rate—rose to 5,000 feet above ground level, and the water at one time was only eighteen inches below the record height of two years ago. At that time, according to the Livingstone Meteorological Officer's reports from Mongu, 300 miles up the river, water was still rising steadily there.

Daily readings are reported to Salisbury, capital of Rhodesia, where they are subjected to analysis by the Inter-Territorial Hydro-Electric Power Commission. This commission, established a little over three years ago following meetings between representatives of the Governments of Northern and Southern Rhodesia and Nyasaland, has as its main function the investigation of possible sites for the development of hydro-electric power. In particular at the present juncture, the Kariba and Kafue gorges have been extensively examined. Detailed ground surveys and borings have been carried out at Kariba and a map of the Kafue Gorge, compiled from data collected by aerial surveys has been prepared. A large mass of hydrographical and geological information has also been obtained from both areas.

The principal concern over the present floods is the Kariba Gorge project. It is considered possible to have about a month's warning of the approach of abnormal floods; information which is of first importance to those responsible for the construction of dams. Engineers are thus able to calculate how much of the rainfall has been absorbed and how much has run off to the sea. The chain of stations at which these recordings are made extends from Balovale, near the Angola border, to the frontier township of Feira, where the Zambesi receives the Luangwa River from Northern Rhodesia and flows on into Mozambique. Other stations are Lukula, Senanga, Sesheke, Kazungulu, Livingstone, Kariba Gorge and Chirundu. At Livingstone records have been kept for nearly 26 years.

Floods in the northern reaches of the Zambesi take about a month to reach the Victoria Falls. The highest level recorded at Balovale so far this season was 37 feet above low water, but by the time the flood reached the Falls it was probably not more than 12 feet above the low level. The reason is that the Barotse Plain and the Caprivi Strip absorb much water temporarily; but this is not a total loss, as when the floods recede the water returns to the river bed and helps to stabilise flow later in the year. Missionaries, district officers of the Northern Rhodesia Government, meteorological officers and officials of the hydrographic branch of the Southern Rhodesia Irrigation Department are among the many who are now engaged in collecting vital information about the behaviour of the Zambesi.

The immense importance which the authorities attach to the recording of data is shown in the decision of the Central African Council, set up towards the end of the war, to entrust a large measure of responsibility for work in connection with the Inter-Territorial Hydro-Electric Power Commission to the secretariat of the Council. The Council's main aim is the closest possible coordination both of policy and action by the three Central African governments in all matters of common interest, while at the same time retaining strictly its function as a purely advisory body. A common fund has been established to which the three territories contribute in varying proportions—Southern Rhodesia ten parts, Northern Rhodesia seven, and Nyasaland three.

Recent experiences in Europe, and probably in more distant parts of the world, underline the great value of what may be generally called long-term information in the initial approach to any considerable hydro-electric development. Its absence has been felt acutely in France, and to a lesser degree in Italy, as well as in Switzerland, Spain and Portugal. For example, when France had tentatively planned appreciable additions to her three principal areas for hydro-electric power supply there intervened a succession of dry seasons the cumulative effect of which was that reservoirs were unable to supply the long term requirements of existing power plants. Quite erroneously this deficiency was in many quarters

attributed to the engineers—actually a complete misconception, since the engineers can proceed only upon the information available to them from any special source, and clearly the data obtained in the case of France was not sufficient for serious assessment so far ahead.

The question of the reliability of such long term "climatic" material is, of course, one for the meteorological scientists, but there will be no dispute about the value of past, as well as future information in reaching decisions on the advisability or otherwise of projects which, first and last, must depend on the behaviour of the elements over a prolonged period. The point is aptly illustrated in the experience of Central Africa. At the Livingstone recording centre it is possible to analyse the statistical data resulting from more than a quarter of a century's observations by experts. In the other direction recent scientific advances in regard to that most hazardous of all tasks —weather prediction—show at least the possibility of getting sufficiently reliable forecasts to justify a decision one way or the other on projected schemes in areas where prolonged periods of drought may be expected to occur.

At the " Science of Weather " exhibition in London, which marked the centenary of the founding of the Royal Meteorological Society, the Lord President of the Council (Mr. Herbert Morrison) referred to the reliance placed by electricity supply undertakings on the work of the Meteorological Office. The five sections of the exhibition itself contained a great deal of evidence of the importance of such records to those charged with the " long term " responsibility of collecting and assessing data on general weather conditions as affecting the operation of hydro-electric undertakings over a prolonged period.

Fondation George Montefiore Prize

THE *Association des Ingenieurs Electriciens* of the *Institut Electrotechnique Montefiore* (31, Rue Saint-Gilles, Liege, Belgium) has announced the quinquennial award of the Fondation George Montefiore Prize, which is given for the best original paper on scientific advancement and on progress in the technical applications of electricity in all fields.

The adjudicators are ten electrical engineers, of which five are Belgian and five foreign, under the presidency of a professor at the *Institute Electrotechnique Montefiore*. The prize for 1950 will be 25 thousand Belgium francs, and the final date for reception of entries is December 31.

Bringing Power to Africa

THE recent flooding of the Zambesi River will recall to many associated with hydro-electric work Sir Dennistoun Burney's great schemes for damming the river. The two Rhodesias, principal countries concerned in the development of the Kariba Gorge scheme, are together as big as Britain, Germany and France together. The gorge itself is not far from the point at which the Zambesi and Sanyati rivers join, and it has been estimated that the proposed dam would be capable of impounding approximately 53 million acre feet of water, generating 750,000 kW. This would be in the region of four times the amount of water impounded by the Great Boulder Dam in Nevada, U.S.A. In effect there would thus be provided near the heart of Central Africa, a great inland waterway 150 miles long and ten miles across to regulate the water necessary for the big power stations. It is probably the biggest hydro-electric engineering scheme ever undertaken in the continent.

Pakistan's New Barrage

WORK has started on Pakistan's Kotri Barrage; it will eventually irrigate over a million and a half acres in the southern area of the Sind Province, diverting the waters of the Indus into canals. The waters will also be used for the production of electric power. Kotri barrage will be over 1,200 yards wide.

Owen Falls Hydro-Electric Scheme

ONE of the first stages in the development of the Owen Falls Hydro-Electric Scheme is the construction of a 66,000 volt single circuit overhead line which will be erected between the site of the Owen Falls power station and the recently constructed Kampala " B " power station. The line is intended to operate initially at 33,000 volts and will supply power from Kampala to assist in the constructional work of the dam. Eventually it will operate at 66,000 volts and will supply Kampala from Owen Falls. This line will be the first of the two circuits to serve this latter purpose. It is believed that this will be the first overhead electrical high voltage line of its kind in East Africa.

The first tower was completed and the last bolt was inserted by the chairman of the Uganda Electricity Board, Mr. C. R. Westlake, M.I.E.E., during a short ceremony. Constructed on steel towers 55 ft. 6 in. the line is some 44 miles long, involving the use of 236 supports. The route follows the new Kampala-Jinja road alignment for a distance of approximately 14 miles, but beyond this point several deviations were necessary.

The consulting engineers to the board are Messrs. Kennedy & Donkin, and the overhead line contractors are British Insulated Callender's Construction Company.

Ahead in India

INDIA'S leaders, from the Prime Minister (Pandit Nehru) downwards have so frequently emphasised the importance to economy of developing the latent water power resources of the country that the announcement of the new Planning Commission's objectives is of special significance. Under the terms of the resolution published in a " Gazette Extraordinary " by the Government of India they include " the efficient exploitation of all the resources of the country to increase production and offer opportunities to all for employment in the service of the community." The Commission's first task will be to assess material, capital and human resources, including technical personnel, and to investigate the possibilities of augmenting resources that are found deficient in relation to the nation's requirements—among which assuredly water power, actual and potential, can be placed high on the list. Next the Commission will define the stages in which the overall development

plan should be carried out, and propose the allocation of resources for the completion of each stage. In all this work the Commission is to act in close consultation with the Ministers of the Central Government and the governments of the states, and the recommendations will in due course come before the Cabinet in New Delhi.

Australia's 20-year Plan

TWENTY years is now given as the time Australia is to take to establish the great east coast electricity grid stretching from Victoria to Queensland. The Australian Minister for Supply and Development (Mr. R. Casey) gave this period recently when he announced that the generating centres would include Morwell and Kiewa in Victoria, the tremendous Snowy River and mountains project, the Clarence River Valley scheme in northern New South Wales, and dams on rivers in Queensland.

The Clarence River dam is to have the status of a national scheme, since it will not only generate electricity and irrigate vast tracts of land but will also act as a means of controlling extensive flooding, of which particularly disastrous examples have occurred in recent years. This work, Mr. Casey hopes, will begin within the next twelve months providing agreement is reached between the Federal, New South Wales and Queensland Governments.

Inland Water Resources of Great Britain

RECONSTITUTION of the Committee to direct the work of inland water supply for Great Britain has been announced, and the Minister of Health and the Secretary for Scotland have appointed the following to the new committee:—

Major-General G. Cheetham, C.B., D.S.O., M.C.; Mr. R. H. Cuthbertson, A.M.I.C.E.; Mr. A. A. Fulton, M.I.C.E.; Mr. W. H. Haile, O.B.E., M.I.C.E.; Mr. M. G. Ionides, A.M.I.C.E.; Capt. W. H. McClean, A.M.I.C.E.; Mr. J. D. Peattie, M.I.E.E.; Mr. N. J. Pugh, C.B.E., M.I.C.E.; Mr. L. A. Rhodes, M.B.E., A.M.I.C.E.; Dr. L. Dudley Stamp, C.B.E.; and Mr. C. A. Wilson, M.I.C.E. The Secretary is Mr. M. R. P. Gregson, LL.B., and communications regarding the work should be addressed to him at the Ministry of Health, Whitehall, London, S.W.1.

The terms of reference of the Committee are "to advise on the surface water survey of Great Britain, on the progress of the measures undertaken, and on further measures required, and in particular to make an annual report on the subject."

The object of the survey can be summed up as the task of making available to Government departments, water undertakers, industry, agriculture, and indeed to all who need it, information about the yield, behaviour and quality of the country's water resources.

For the present the committee will be concerned in the main with surface water, but they may be asked from time to time about underground resources. The field work will be undertaken by the new river boards, who are given wide powers for the purpose, and by water users throughout the country.

The Chairman (Major-General Cheetham, of Surbiton, Surrey) was director-general of the Ordnance Survey until last June. Mr. Haile, of Nottingham, and Mr. Rhodes, of Malvern, are both experienced in the work of catchment boards, the former being engineer to the River Severn Catchment Board.

Electricity interests are represented by Mr. Peattie (London), deputy chief engineer (generation) to the British Electricity Authority, and Mr. Fulton (Edinburgh) chief hydraulic and civil engineer to the North of Scotland Hydro-Electricity Board.

The Federation of British Industries has as its representative Mr. Ionides (London), deputy director of the Society of British Aircraft Constructors, who is familiar with the requirements of industry in regard to water supply, and is the author of works on the water resources of Transjordan and the rivers Euphrates and Tigris.

Power Generation in Tasmania

THE recent report of the Tasmania Hydro-Electric Commission shows that the output totalling 920.3 million kWh for the year under review, is 13 per cent. more than that in the previous year. There are five major hydro-electric plants, and ten further dams are either being investigated, or in various stages of construction. Capital expenditure on development work has reached £2,120,082, the largest item being for the Nive power development scheme.

Plant from a number of English manufacturers is being supplied to the station at Tungatinah where there are four 35,000 h.p. turbines (parts of these being manufactured in Australia), the turbines themselves being from Boving and Company, and the alternators from the General Electric Company. At Waddamana the fourth 15,000 kVA turbo-alternator has been supplied by the English Electric Company.

Paraguayan Development Postponed

CONTRARY to recent reports in the Press that large-scale hydro-electric power developments were contemplated on the Tebicuary river in Paraguay, we understand that no progress is likely to be made on the scheme for some time. It appears that the reasons are twofold—the lack of exchange for purchasing hydro-electric plant from foreign countries, and the low level of industrialization which would make uncertain within a reasonable period of time the disposal of the energy produced by such a station.

Brush (Far East) Limited

BRUSH (FAR EAST) LIMITED has been formed with registered offices in Ocean Buildings, Singapore, to be factory representatives of Petter, Petter-Fielding, McLaren, Mirrlees, National and Meadows Diesel engines and of the products of Bryce Fuel Injection Limited and the Brush Electrical Engineering Company in the following countries: Malaya, Indonesia, French Indo-China, Borneo, Sarawak, Siam, Philippines, China, Hong Kong, Japan, Formosa and Ceylon.

Mr. H. F. Clements is chairman and Mr. A. C. Geddes, Mr. F. A. Vaughan, Mr. A. A. King are directors. The individual companies will, however, continue to sell their products through their existing agents.

The Mississagi River in Northern Ontario—site of the Tunnel hydro-electric development.

The Zezere Hydro-Electric Scheme

A description of the Castelo do Bode development, with some exclusive photographs taken during a recent visit to the site

La mise en valeur du potentiel hydro-électrique de la Zezere, tributaire du Tage, en Portugal, est l'une des entreprises les plus importantes du genre dans les années récentes. Des sociétés britanniques ont effectué une très grande partie des travaux. L'exploitation de la Zezere est à quatre étages, avec des barrages à Cabril, Bouca, Castelo do Bode et Constancia (d'amont en aval). La station génératrice la plus importante est celle de Castelo do Bode, à 100 km. au nord-est de Lisbonne. Elle est construite en priorité et les travaux y sont aujourd'hui près d'être terminés. Elle est décrite çi-dessous.

Uno de los más importantes contratos hidroeléctricos de estos últimos años, una gran parte del cual ha sido ejecutado por firmas británicas, es el relacionado con el desarrollo del potecial hidroeléctrico del rio Zezere, un tributario del Tago, en Portugal. El rio Zezere está siendo desarrollado en cuatro fases, construyéndose presas en Cabril (principiando desde el extremo de aguas arriba), Bouca, Castelo do Bode y Constancia. De estas fases, el proyecto de Castelo de Bode es el más importante, a unos 100 kilómetros al noroeste de Lisboa, que en la actualidad está casi terminado; sin embargo, es el primero en orden de prioridad de construcción.

ONE of the most important hydro-electric contracts in recent years, of which a very large proportion has been carried out by British firms, is that concerned with the development of the hydro-electric potential of the Zezere river, a tributary of the Tagus, in Portugal.

The river Zezere is being developed in four stages, dams being erected at Cabril (commencing from the upstream end), Bouca, Castelo do Bode, and Constancia. Of these the largest is the Castelo do Bode scheme some 100 km. north-east of Lisbon, which is now nearing completion; it is, moreover, the first in order of priority of construction.

It was in 1945 that the Portuguese Government commenced work on a major scheme to increase the supply of electrical energy in order to implement their policy of building up the basic industries of the country, and three companies were formed — the

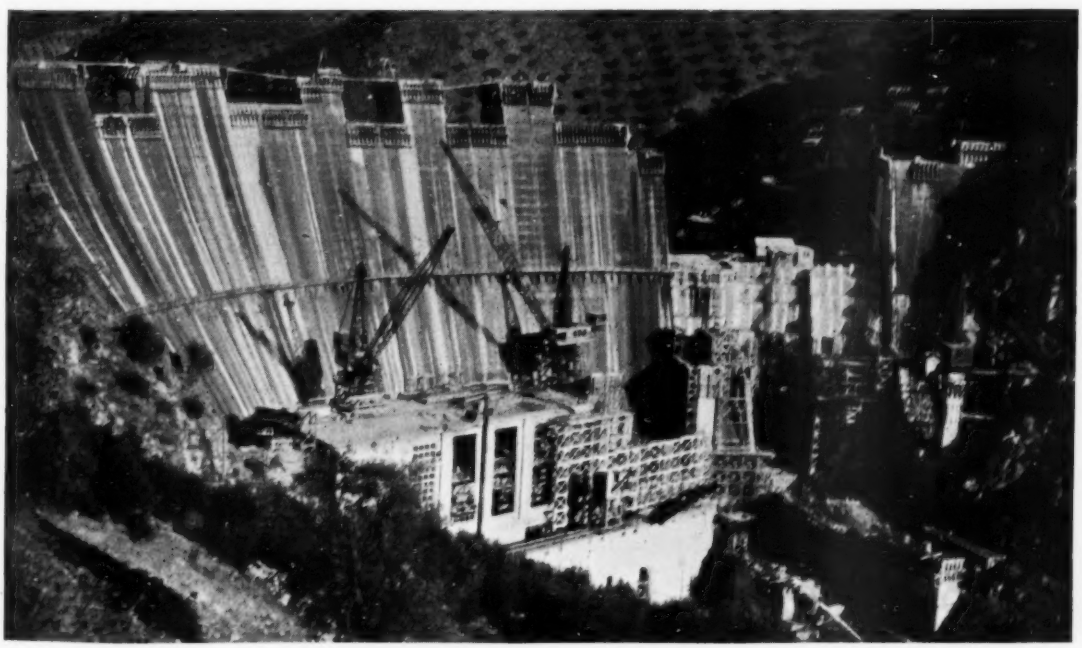


Fig. 1: The Castelo do Bode hydro-electric station on the Zezere river in Portugal: general view of the dam construction

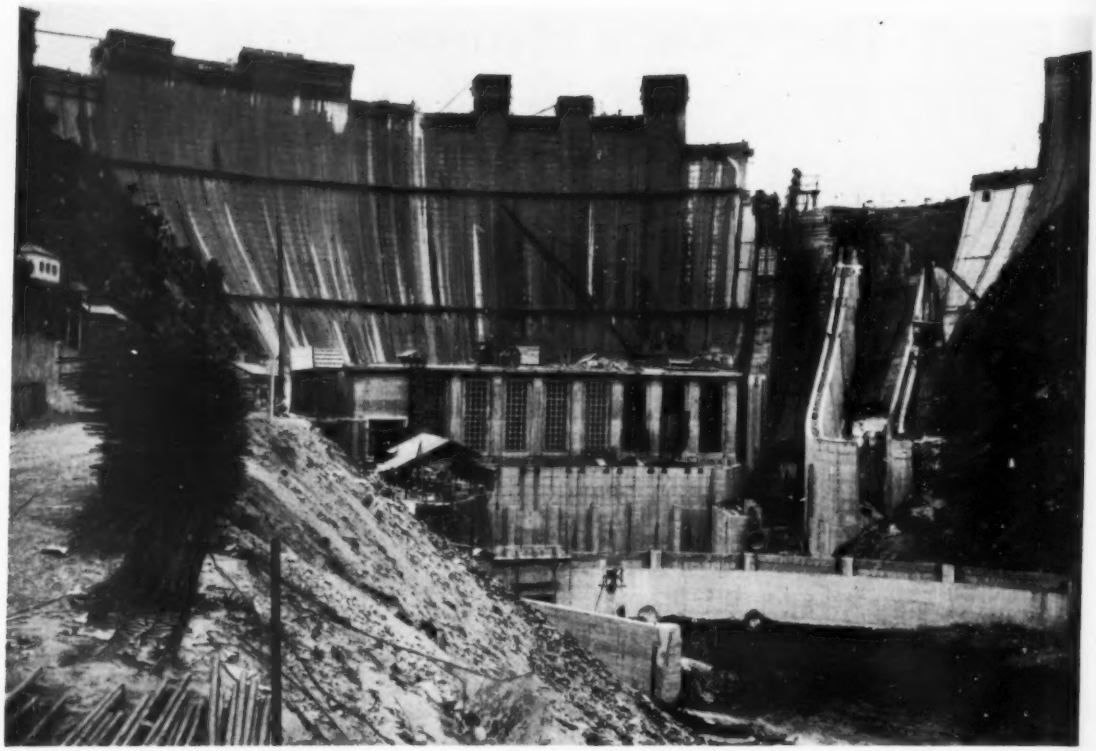


Fig. 2: The Castelo Dam showing the power station at the foot and spillway on the right

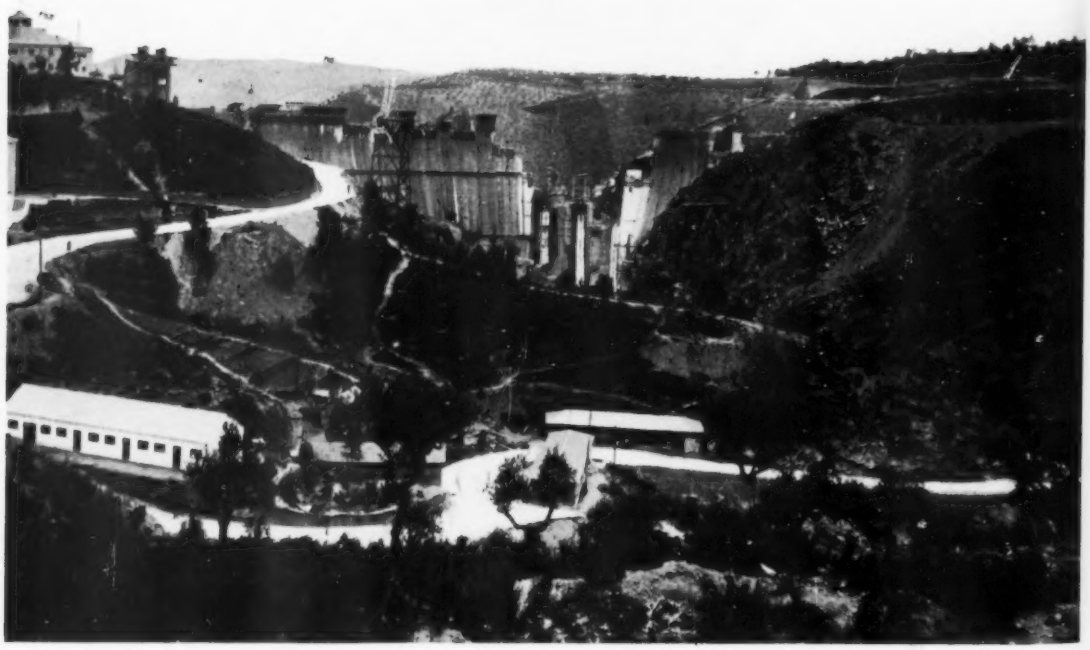


Fig. 3: The upstream side of the dam, taken recently, showing part of the area to be submerged by the new reservoir

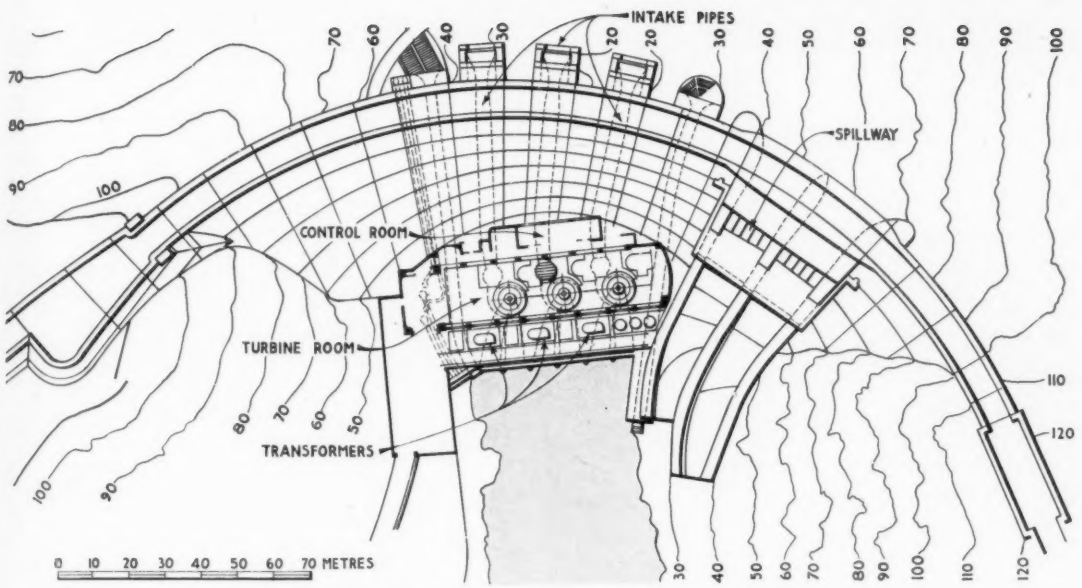


Fig. 4: General Plan of the Castelo do Bode Dam

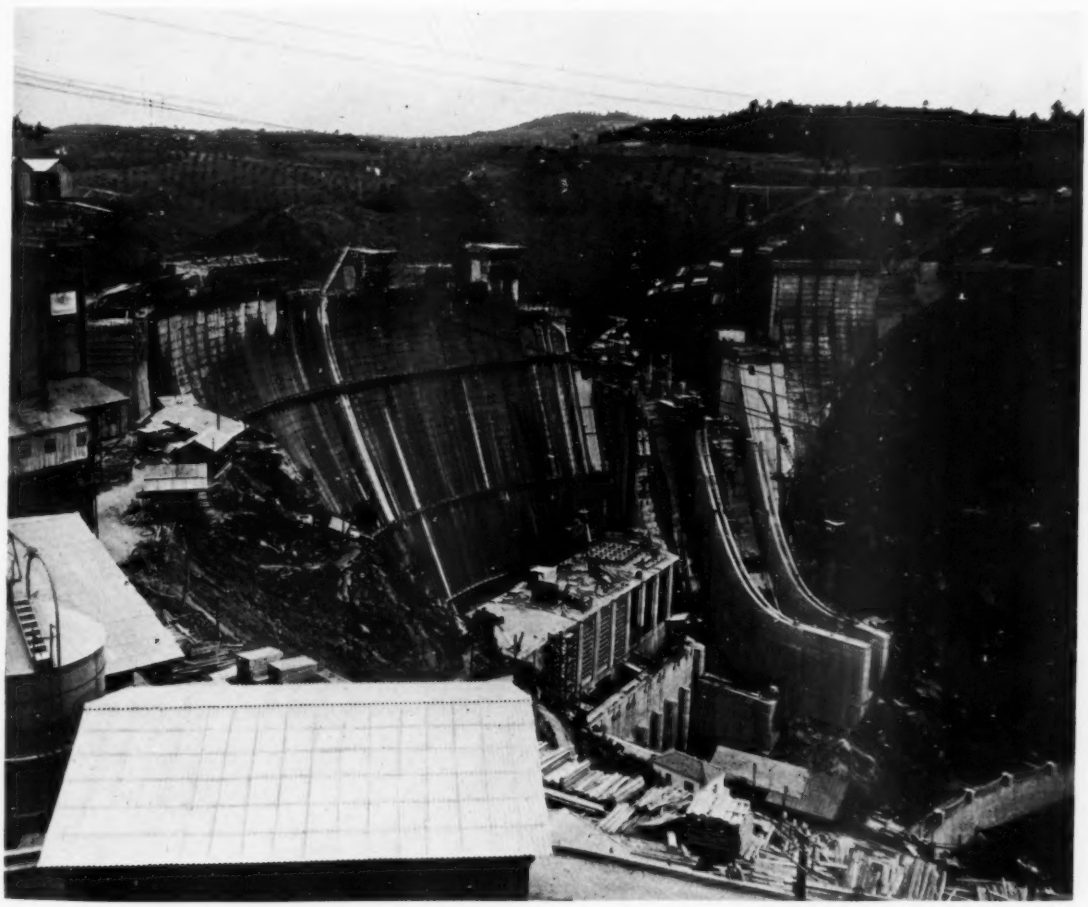


Fig. 5: The Power House: general view showing also the ropeways used in placing the concrete

Fig. 6: Another view of the Castelo do Bode Dam with the spillway and power house

Hidro Electrica do Zezere, the *Hidro Electrica do Cavado*, and the *Companhia Nacional de Electricidade*—to carry out the Government's plans. The first two companies were charged with the duty of developing the hydro-electric potential of the rivers Zezere and Cavado respectively, and the C.N.E. was formed for the purpose of constructing and operating high tension transmission lines to distribute the energy generated by the other companies.

Over that part of the Zezere river which is considered suitable for hydro-electric development there is a total fall of 900 feet. The catchment area is 3,950 square kilometres, and with an average rainfall the river flow is 75 cubic metres a second. The river lies in a hydrographic basin over a great part of which there is a high rainfall; further, the terrain is such that at various points on the river it is feasible, both economically and physically, to create large storage lakes. These would help also to control floods and so assist in the ordered development of agriculture.

Dam and Spillway

The dam erected at Castelo do Bode is of the thick arch type and has a height of 380 feet. The radius of

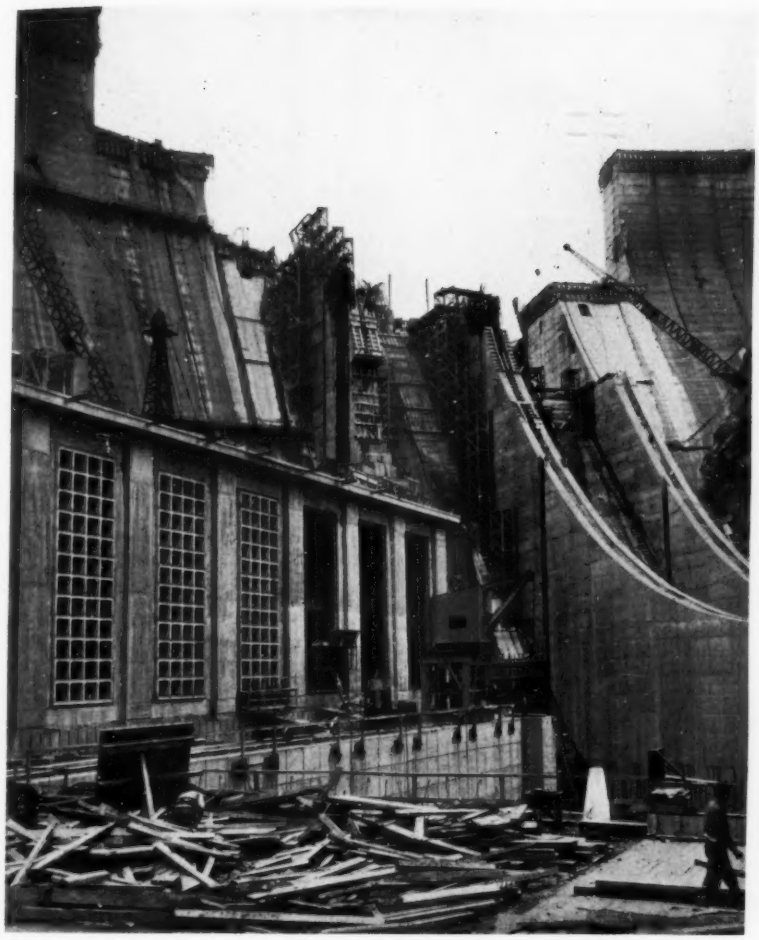


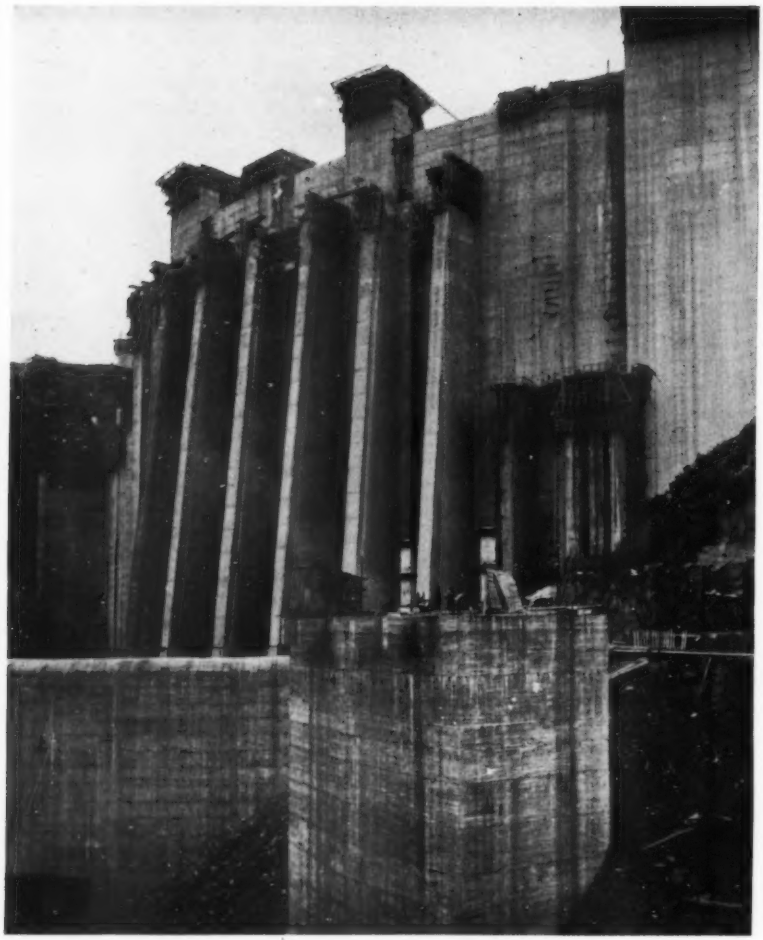
Fig. 7: The Castelo power station showing the hoist for the draft tube gates (right centre) and the platform on which the transformers will be mounted

Fig. 8: Part of the concrete mixing plant and ropeways

the vertical face on the upstream side is 500 feet; 420,000 cubic metres of concrete are used in the construction. The power station is situated at the foot of the dam, and near the left bank is the spillway. The spillway is of a special design, since great care had to be taken to prevent damage to the river bank by the discharge of large quantities of water. Two concrete channels narrowing towards the outlet were designed to shoot the water away from the immediate surroundings. The scheme provides for a discharge of 4,000 cubic metres of water a second.

The main civil engineering work was carried out by the Portuguese firms Monez da Maia and Vaz Guedes Ltda, with the aid of a Swiss contractor, Conrad Zschokke. They have employed, almost exclusively, British-manufactured constructional engineering plant. Messrs. Pauling & Company, of London, formed a group of British suppliers of every type of constructional equipment, and coordinated its design and dispatch. The plant was purchased instead of hired, and was divided into various sections according to the necessary operations—the production of concrete, and its transportation and eventual deposition on the dam.

To obtain aggregate, sand and gravel from the river bed is being extracted by six drag lines, each equipped with a bucket of 1.2 metres cubic capacity and producing 50 tons an hour. These are situated over 2.4 kilometres away from the dam site, and the material is then transported by means of 15-ton trucks to three washing and screening plants. Each of these has a capacity of 100 tons an hour;



Cement has been supplied by the *Companhia Cemento Tejo*, and is carried in metallic containers from Alhandra to Santa Cita by rail, and from there to Castelo do Bode by truck. Six fabricated storage bins of 500 tons storage capacity, each provide a stock pile.

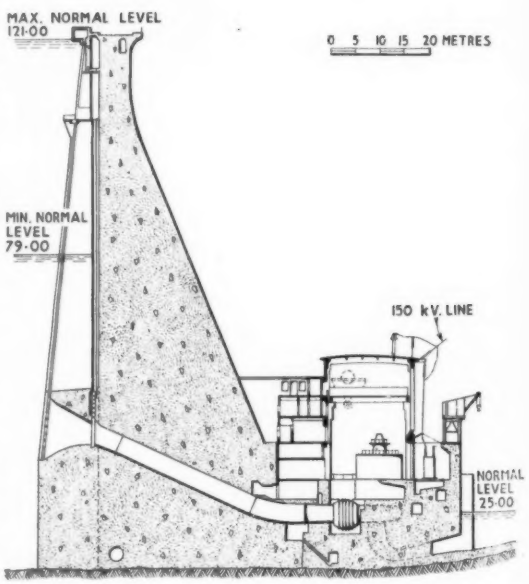
The Power Station

The power station at the foot of the dam is of concrete construction and the face of the dam constitutes the back wall. It houses three English Electric Francis type turbines designed for an output of 62,000 h.p. under 80 metres head. Due to variations in the level of the water behind the dam, the head is expected to fluctuate between 53 and 95 metres when the turbine output will be 33,000 h.p. and 73,000 h.p. respectively. The turbines are direct coupled to English Electric two bearing type alternators running at 214 r.p.m. with a maximum output of 57,400 kVA at 15,500 volts 3 phase. For line charging purposes the alternators are capable of delivering 25,000 kVA. The design also allows of the alternators being run as synchronous condensers for power factor correction, a feature that will be useful if ever there is a water

Fig. 9 (above): Upstream side of the sluice gates in course of construction. Fig. 10 (right): Cross-section of dam

two twin cable ropeways are then used to transport the graded raw material from the screens to stock piles. These ropeways have a capacity of 225 tons an hour each. The material is then taken by conveyor belts which feed single cable ropeways to carry the aggregates over a distance of about two kilometres to the main mixing plants.

The mixing plant, which was constructed by Messrs. Blaw Knox, is in two parts, one on the level of the power station, and the other roughly at the level of the top of the dam. At the top mixing station the concrete is delivered in dumpers which transport it to skips from whence it is placed in position. These skips are handled by four ropeways which span the entire width of the dam. They are of 10 tons capacity, and comprise movable mass at one side of the river and fixed masts at the other side. The movable masts are on rails so that the whole area of construction work can be covered by suitable positioning of the towers. The upper mixing plant can produce 120 cubic metres of concrete an hour, and the second mixing plant situated at power station level another 50 cubic metres an hour.



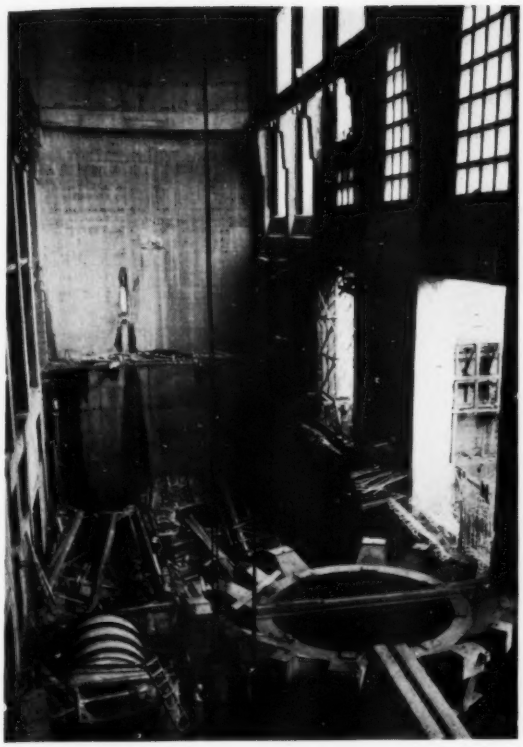


Fig. 11: Interior of the turbine room, showing the first turbo-alternator in course of construction

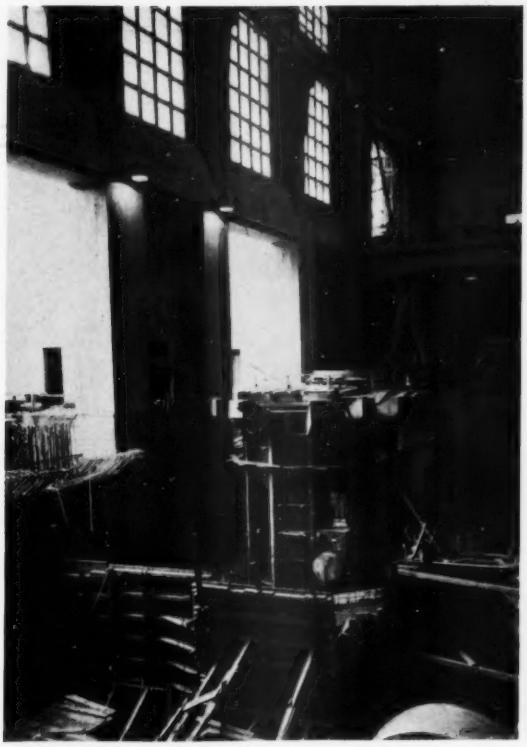


Fig. 12: The alternator mounting in the turbine room at the Castelo station

shortage at Castelo and power for Lisbon is imported from the more northern stations. For condenser service the units will be run up in the normal way and synchronised. The turbine is then shut off, the water level depressed to below runner level by compressed air and water spray fed to the seals to keep them cool.

At the inlet to each turbine will be an 11 ft. nominal bore English Electric "straight-flow" type of valve. Furthermore, provision is made for removing a section of the draft tube cone so that the runner can be lowered on to a bogie, run in through space so freed, and thereby avoid the necessity for removing any of the upper parts when overhauling the turbine.

In the power station there are also two auxiliary sets, for house service supply, each rated at 1,300 h.p. and coupled to an 1,125 kVA 1,000 r.p.m. 380 volt 50 cycle 3 phase alternator.

The three main penstocks, 4 metres diameter, pass through the dam and have intake gates of the caterpillar type together with racks for stopping debris. Each alternator is connected by bare copper and bolted links either to its own transformer or to busbars connecting to a water resistance type test tank.

The transformers, of the forced oil circulation type, raise the voltage to the nominal 150 kV of the transmission system. They are fitted with off load tappings on the high tension side. They are of the outdoor type and are located over the draft tube on the downstream side of the station. The high voltage switchgear is of outdoor high speed air blast pattern to be arranged in a low level switching station on the right bank of the river about 600 yards from the generating station and connected to it by S.C.A. overhead lines.

At present three incoming generator and three outgoing feeder circuits are visualised at 150 kV. Three 60 kV feeders are also contemplated. At a later date three more 150 kV feeder equipments will be installed.

Two control rooms are to be provided: one at the substation to take care of the main transmission and load despatching; the other is in the generating station where control of the sets is to be effected on telephonic instructions from the load despatch. The transformers and switchgear are manufactured by Metropolitan-Vickers Electric Company.

Construction Progress

To permit construction work to proceed a diversion tunnel for the river water had first to be constructed, together with two coffer dams, one above and the other below the main working site. They were started in May, 1946; in August, 1947, the water was first diverted through the tunnel so that building could be commenced in September of that year. Excavations for the dam foundations also began in 1947. It is expected that by the end of this year the station will be in operation: thus the construction, from start to finish, of the Castelo do Bode scheme of the Zezere development promises completion within four years.

MR. ARTHUR DAGNALL, of Westbourne Road, Lower Walton, Warrington, Lancashire, has been appointed a senior supervisor (water supply) in the Public Works Department, Uganda.

He was born at Warrington, and educated at St. Barnabas School, and Warrington Technical Institute.

The Loch Lomond: Sloy Power Station and pipelines in foreground

Loch Sloy

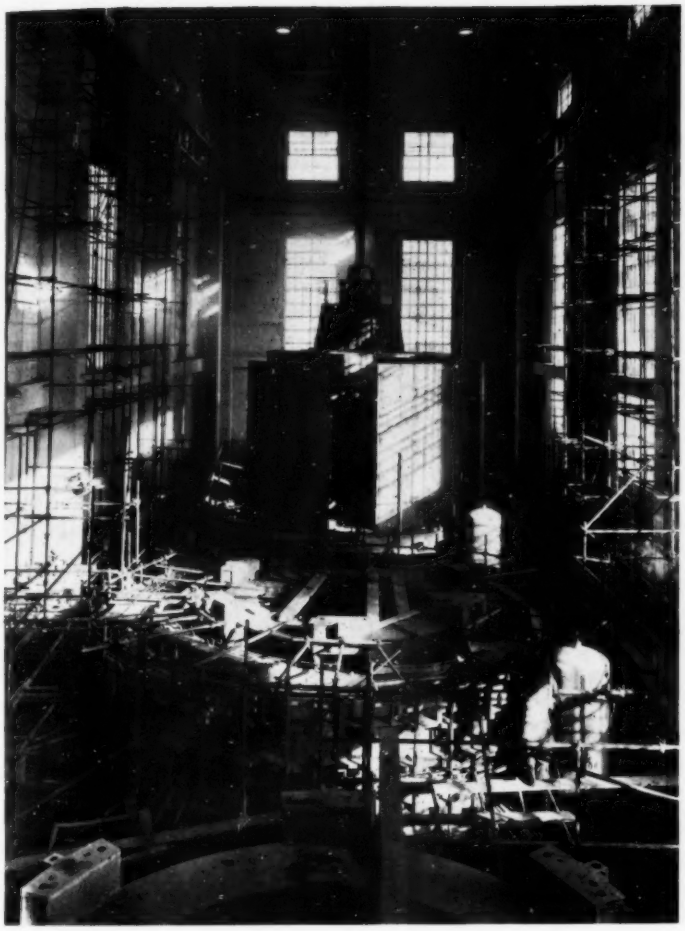
The first major hydro-electric scheme in the North of Scotland Hydro-Electric Board's power extension programme was inaugurated on March 6, when Mr. Thomas Johnson, P.C., Chairman of the Board set in operation the first of four water turbines at the Loch Sloy Power Station

A DETAILED description of the Loch Sloy site and station plant will appear in a subsequent issue of WATER POWER; but we give at once some outstanding particulars of this scheme, with a total capacity of 130,000 kW, which will, on completion later this year, be the largest hydro-electric station in Great Britain.

From an enlarged catchment area the waters of Loch Sloy are impounded at its eastern end by a dam which is 165 feet in height and 1,160 feet in length, containing over 200,000 cubic yards of concrete, of the massive buttress type. The water flows through a one and three-quarter mile long horseshoe-shaped tunnel through Ben Vorlich, which has an outlet 642 feet above the power station on the banks of Loch Lomond. The connection between the tunnel and pipe lines is through a valve house where each pipe line is protected by a butterfly valve and automatic air valve. From here four lines of electrically welded steel pipes ten feet in diameter run to the power station, where they taper to about seven feet diameter. When the dam is full, the gross head at the turbine level is 910 feet.

The main contractors for the dam were Balfour Beatty & Company, and the quarry at Coiregrogain (from which the aggregate was produced) was operated on behalf of the board by Keir & Cawder Ltd., of Glasgow. The main tunnel was constructed by Edmund Nuttall Sons & Company (London), and Sir William Arrol & Company, of Glasgow, supplied the steel pipelines.

In the power station are four 32,500 kW Francis turbines; these machines and their associated alternators were supplied by The English Electric Company. The turbines are of the vertical shaft high-pressure reaction type of 45,000/50,000 b.h.p. operating under a head varying from 900 ft. to 720 ft. and running at 428 r.p.m. They are protected by valves of the cylindrical balanced type and are fitted with synchronous by-pass or discharge regulators of the cylindrical balanced and diffusing type. The spiral



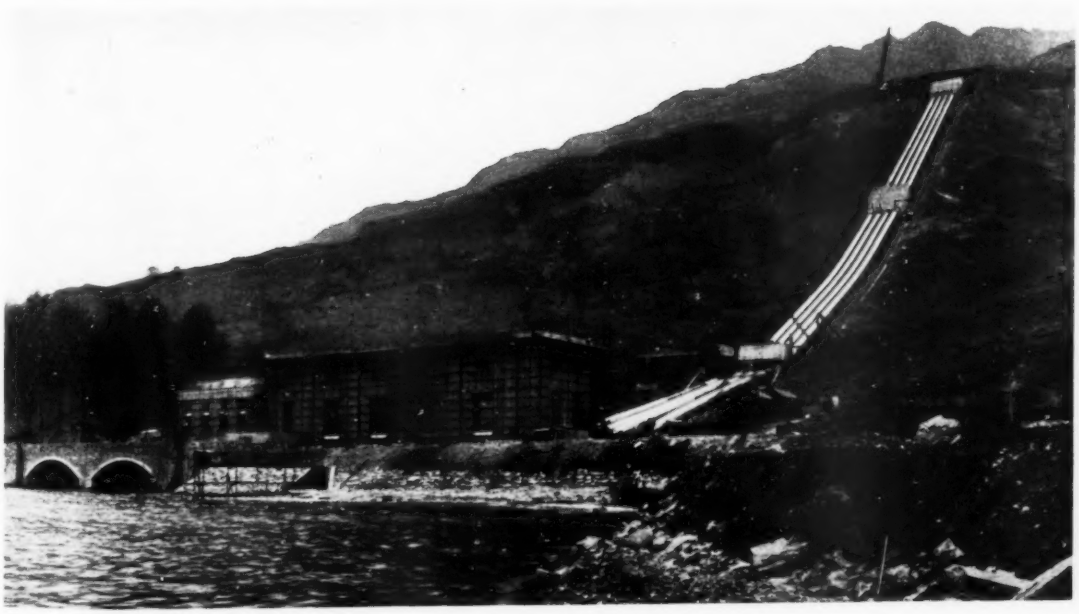
casings of the turbines are made of cast steel, in one piece, and weigh 30 tons each.

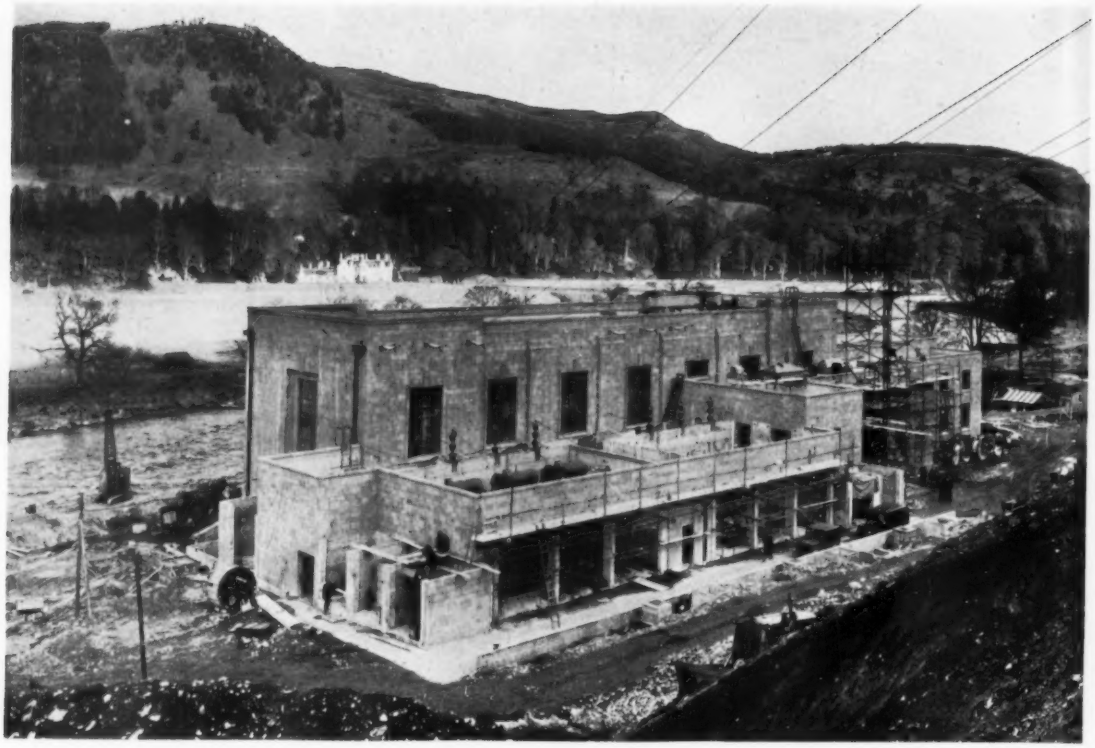
The alternators are of the two bracket type, the combined thrust and guide bearing being mounted in the upper bracket above the rotor; the second bearing is below the rotor. The stator frame, of steel elements welded together, is divided into two sections for transport purposes. The main pilot exciters are mounted above the alternator and are totally enclosed. CO_2 fire extinguishing equipment is fitted.

The output of the station is fed to the 132 kV Grid system by way of the switching station at Inveruglas. This is of the single busbar type with four generator circuits and initially six feeder circuits, which are eventually to be increased to nine, together with the bus section circuit breaker. Each generator is direct connected to its own transformer located outdoors on the upstream side of the power station. From here the power is taken by overhead line to the switching station. Circuit breakers are of the bulk oil type with multiflow grid arc control devices, and are rated at 1,500 MVA, being equipped with high speed pneumatic closing mechanisms. The power station control room through supervisory apparatus is in charge of the equipment.

Fig. 2: Interior of power station showing turbines in course of construction

Fig. 3: Tailrace bridge and pipelines





Rear face of the station building showing transformer platform

Clunie Power Station

In the January-February issue the dam and tunnel of this important project were described; we now give particulars of the power house and electrical dispositions

THE power station building measures 230 feet long by 70 feet wide and was designed by the Consulting Engineers in co-operation with Messrs. Tarbolton and Ochterlony, Architects, Edinburgh. It consists of a steel-frame building with 10 inch reinforced concrete walls, the exterior surfaces of which are faced by attractive synthetic stone slabs two inches thick, supplied by Messrs. George W. Bruce, of Aberdeen. The station has been designed for manual operation and equipped on a generous basis with a fairly spacious control room and administrative offices. It was chosen as the maintenance centre for the Tummel Garry group of stations so that a repair shop with a light crane and space for considerable machine tool equipment has been provided. An imposing entrance hall and liberal storage space are features of the building. The turbine room, which has a 110 ton crane manufactured by the Clyde Crane & Engineering Co. Ltd., measures 154 feet long by 45 feet wide.

The generating units consist of three 20,400 kW M.C.R. (max. continuous rating) 214 r.p.m. vertical Francis turbo-alternators generating at 11 kV, 0.9 p.f. The net head varies from 165 feet to 145 feet and the turbines are designed to give their maximum efficiency at an output of 16,000 kW and 155 feet head. They are of standard design with welded plate steel spiral casings and cast steel guide vanes and runners with stainless steel protection on the areas of the blades exposed to cavitation. The inlet valves are of the hydraulically operated butterfly type, 11 feet diameter with a rubber hose sealing. An automatic pressure-relief valve is supplied for each turbine. The alternators, rated at 22,667 kVA continuous maximum, are of umbrella design with single thrust and guide bearing mounted below the rotor. They have closed circuit cooling with provision for diverting a portion of the air from each alternator for heating the turbine room. Make-up air is obtained through filters and hand operated louvres in the alternator plinths. Cooling water for the air coolers is taken from the spiral casings. The sets have a stator bore of 17 feet 7 inches and runner diameter of 9 feet 3 inches. The governor equipment comprises the actuator, main

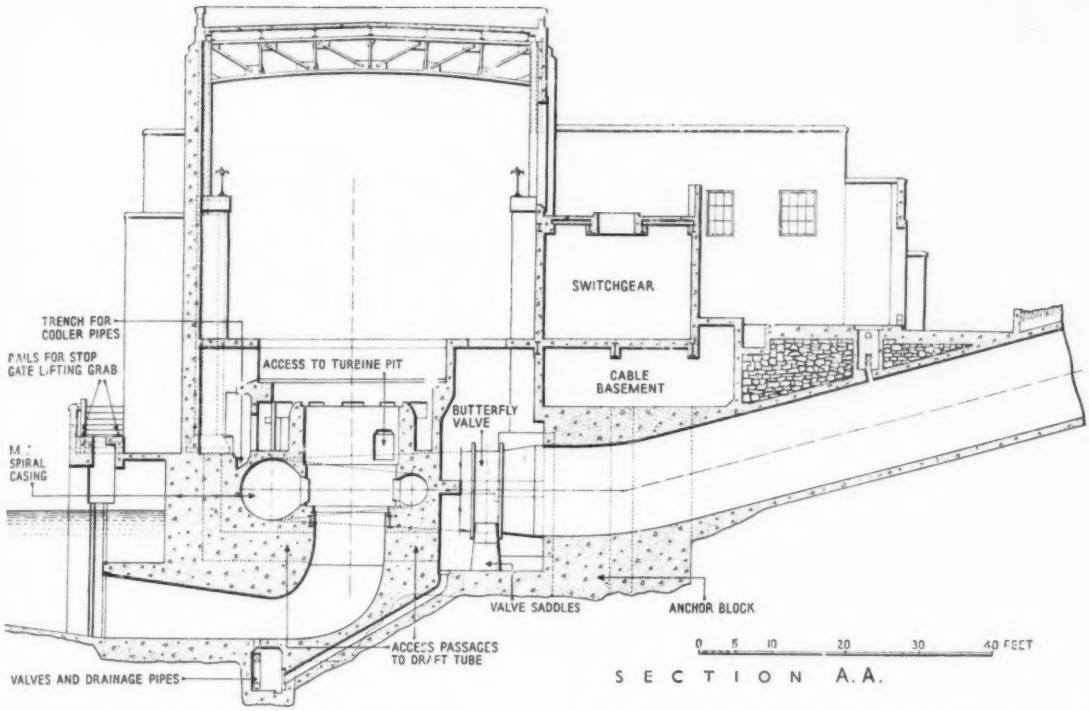


Fig. 2 (above): Cross sectional elevation through the power house

Fig. 3 (below): A recent view of the Clunie power house

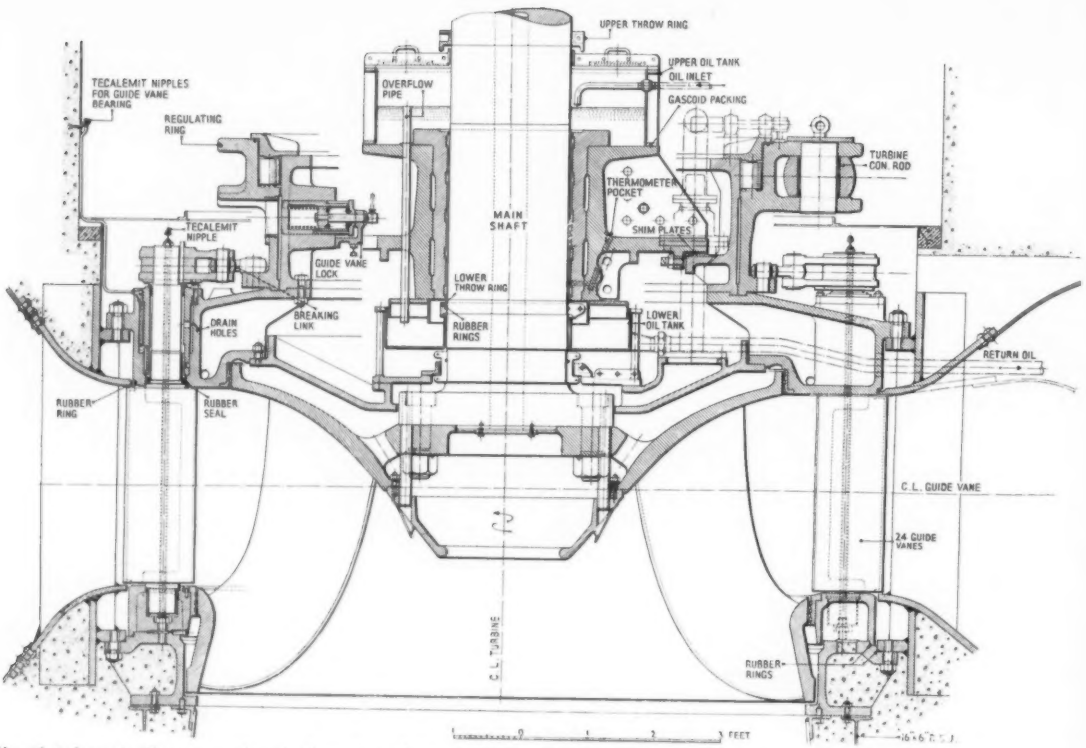
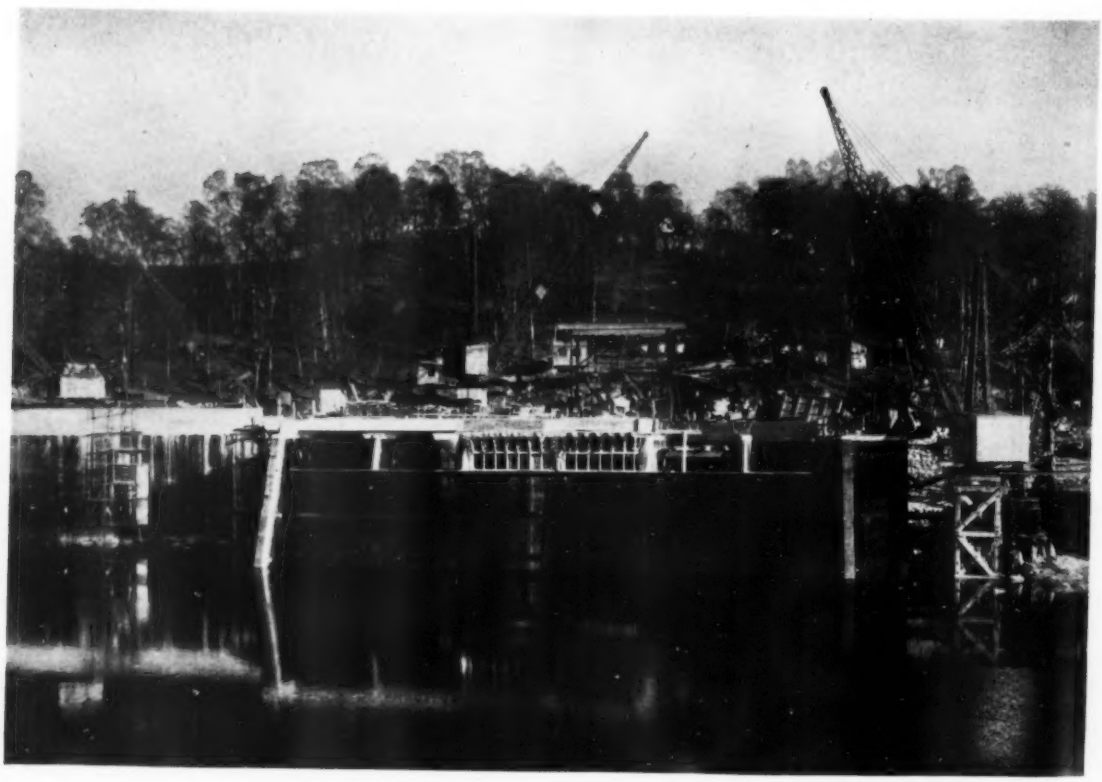


Fig. 4 (above): Cross sectional elevation through one of the turbines

Fig. 5 (below): View of the intake, showing screens



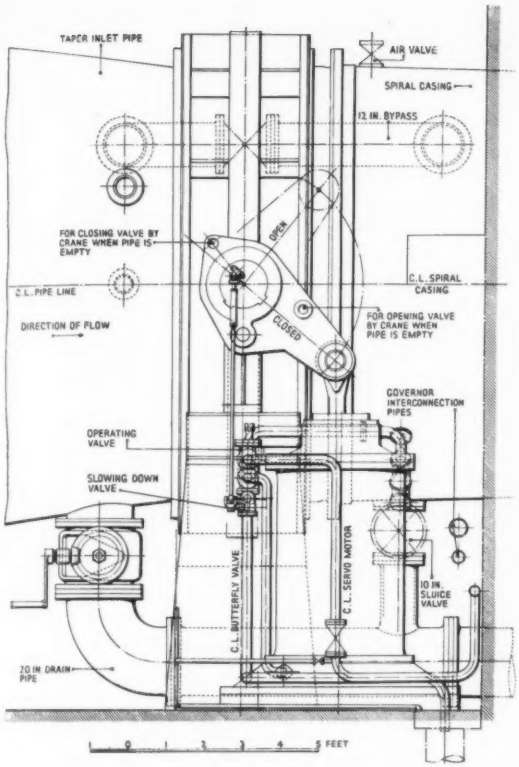


Fig. 6: Butterfly valve controlling turbines

servometer and oil pumping units for each machine. A stand-by governor oil pump driven by an 18 h.p. Pelton turbine delivers into an oil bus pipe connecting the three main governor oil pumps. Compressed air for the initial charging of the governor air vessels is provided by a Pelton turbine-driven air compressor common to all machines. Each oil pumping unit is fitted with an automatic oil operated air compressor which maintains the correct air volume in the air vessel. The provision of the Pelton auxiliaries facilitates starting the station without external power in the event of total shut-down of the station.

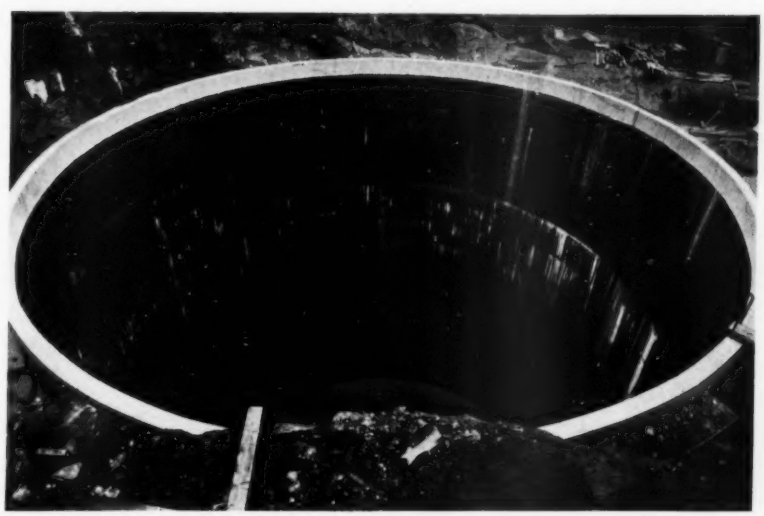
The alternators were manufactured by the B.T.H. Co., Ltd., and the turbines were designed by Boving & Co., Ltd., and manufactured by John Brown & Co., Ltd. The first machine was turned round on Sunday, 12th February, and began to contribute current to the grid in March.

All items of equipment which the turbine driver needs for manual control of the turbines are accommodated on the turbine panels at generator floor level, viz. machine controls, gauges and alarm indicators; also at this floor level are the field control pillars, inlet valve emergency control pedestals, unit auxiliary boards and the governor actuators. The only equipment on the downstream side at main floor level consists of the hot air discharge "chests" and three pedestal type flow meters which indicate, integrate and record the water used by each turbine. All the remaining machine auxiliaries are located on the lower floors.

The main switchgear is of single busbar, oil filled metalclad type, 11 kV, 750 MVA rating manufactured by the B.T.H. Co., Ltd. It is divided into two sections in separate compartments of the switch house which is an annexe of the turbine house, and provision is made for an outdoor type bus section reactor rated at 5 per cent. on 20,000 kVA. As briefly mentioned in Part I of this article,* Clunie and Pitlochry stations are intimately linked and from the electrical aspect may be regarded as one. The Pitlochry generator switches are included as part of the Clunie 11 kV switchboard and although the machines at Pitlochry station are started and stopped manually within Pitlochry station, operations of loading and synchronising are carried out from the control room at Clunie. The main feeder transformers (Bruce Peebles & Co., Ltd.) consist of two banks of three single-phase units, each bank rated at 60 MVA. They are situated on a concrete raft behind the switch house at the back of the station and immediately over two of the three pipelines. The water for the transformer cooling and fire protection is taken from the centre pipeline though pressure-reducing valves and is discharged to the tailrace. On-load tap changing equipment has not been provided but provision has been made for its inclusion later if required.

The control room contains, in addition to the usual instrument and mimic diagram panels a control desk, relay and voltage regulator panels and a panel for hydraulic indicating and recording instruments. On this latter panel are displayed and recorded measurements of reservoir levels and river flow below both Clunie and Pitlochry dams and duration of spilling conditions and compensation spates. Automatic release and indication of position of the intake gate for

Fig. 7: The top of the surge tank



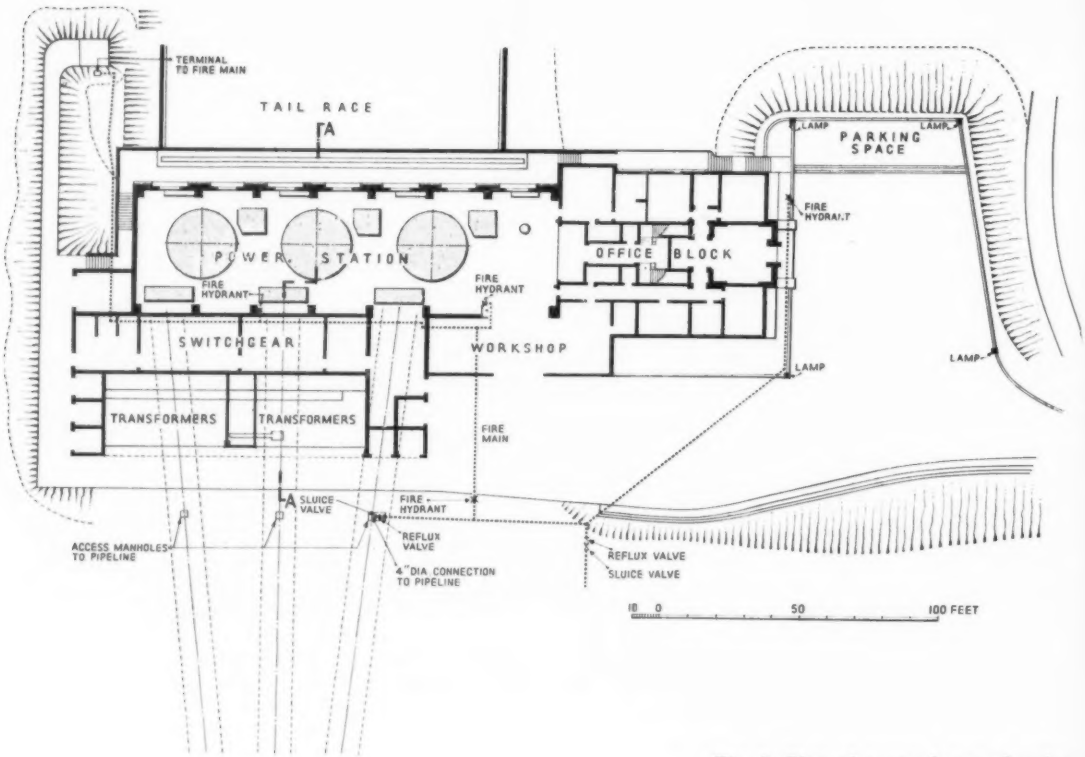


Fig. 8: Plan of power house showing office block, and accommodation for switchgear and transformers

Fig. 9 (below): Elevation of power house from riverside

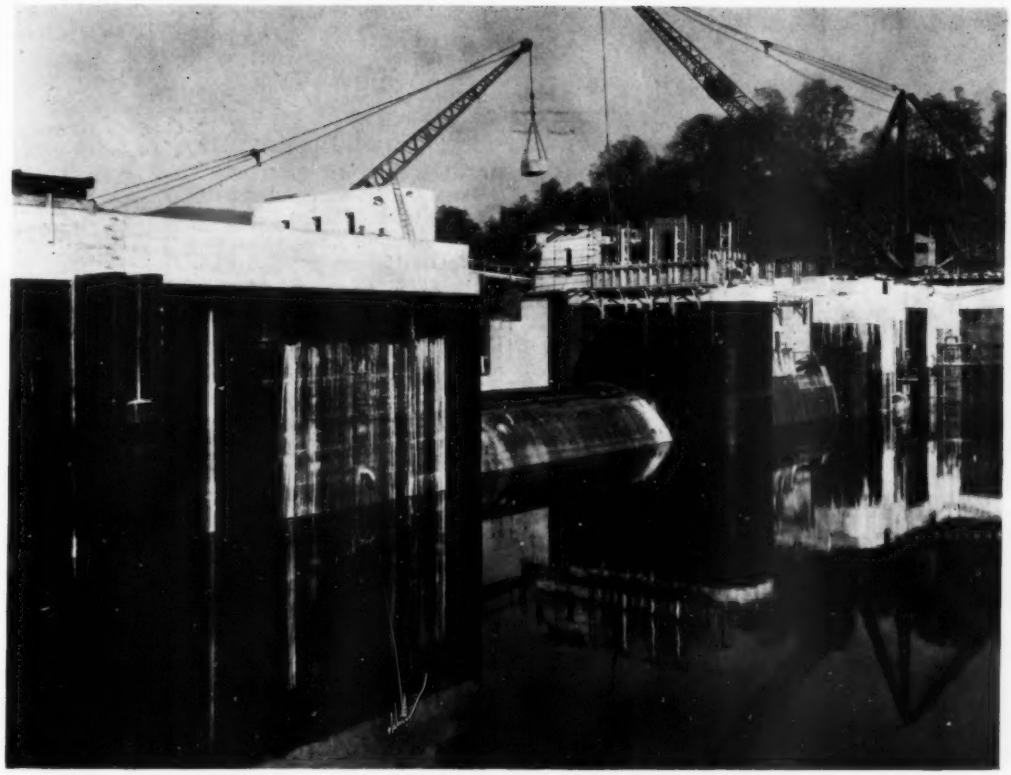


Fig. 10: The dam in process of filling, with the drum gate partially submerged

Clunie Tunnel are also provided.

A central alarm panel is provided in the control room to give detailed display of operation of all the various fault, protective and warning devices on both mechanical and electrical plant, and also to give alarm of dam spill or intake gate release by the excess flow device. Similar quantities are displayed on the same central alarm panel for Pitlochry dam and power station.

The output of the station is taken by a double circuit steel tower 132-kV steel-cored aluminium overhead line to a new 132-kV substation now nearing completion between Tummel Bridge and Errochty power stations. This substation will become the collecting point and also the control centre for the whole group of stations in this catchment area and from it the power surplus to that required in the North of Scotland Hydro-Electric Board's area will be transmitted southwards to the British Electricity Authority's system at Bonnybridge and Abernethy.

For the purpose of providing power supplies for the construction of the works a 33-kV overhead line was erected in the early stages of the scheme from the existing network at Tummel Bridge along the right-hand bank of the River Tummel as far as Clunie power station. Thence supplies are given to the Pitlochry works over an 11-kV cable. When the works are completed a connection will be made from this cable to the Pitlochry town network and the whole will serve as one section of a ring main between Tummel Bridge and Pitlochry. Both Clunie and Pitlochry power stations will have connections from this ring main which will provide one source of low voltage supply for auxiliary plant in the power stations when the main generating sets are shut down. The 175-kW Francis turbo-alternator set installed in Clunie dam (referred to in Part I of this article erroneously as a Turgo type) and which is driven by the compensation water which it is necessary to pass through the dam during certain months of the year, will deliver its output into this ring main. The latter will also provide a source of power for operation of the various electrical equipment installed at Clunie dam and tunnel intake.

In concluding this description we have pleasure in acknowledging our indebtedness to the Chairman of the North of Scotland Hydro-Electric Board, Sir Edward MacColl, for permission to inspect the Clunie operations and we also express our appreciation of the kind assistance given to us by Sir Alexander Gibb & Partners and Messrs. Merz and McLellan, consulting engineers for the civil and electrical work respectively, in supplying many of the data incorporated in the article. A list of the main contractors for the Clunie project is appended:—

Tunnel - - -	The Cementation Co. Ltd.
Dam - - - -	George Wimpey & Co. Ltd.
Valves, etc. -	Glenfield & Kennedy Limited
Pipelines - -	P. & W. Maclellan Limited
Power Station -	A. M. Carmichael Limited
Turbines - -	Boving & Co. Ltd.
Alternators - -	British Thomson-Houston Co. Ltd.

* ***WATER POWER, Jan.-Feb. issue, page 20***

Performance of Francis Turbines

By PROF. DR. ING. IGINO TESSARI. The influences of frequency variation on the efficiency of Francis type water turbines, and a consideration of the advantages of statistical methods in predicting their performance

Des effets de la variation de fréquence sur le rendement des turbines hydrauliques du type Francis, et des avantages de la méthode statistique dans la prédiction de leur fonctionnement. L'auteur examine le comportement du type de turbines actuellement employées en Italie à 42 cycles par seconde, par rapport á leur rendement lorsque la fréquence est augmentée à 50 cycles. La turbine Francis a été choisie pour cette étude parce que les turbines hélicoïdales fonctionnent bien à des régimes différents; elles ont aussi le meilleur rendement sous des charges variables.

La influencia de las variaciones de frecuencia sobre la eficiencia de las turbinas hidráulicas de tipo Francis y la consideración de las ventajas resultantes del empleo de métodos estadísticos para predicir su funcionamiento y rendimiento. El autor considera el funcionamiento de las ruedas hidráulicas de turbina del tipo empleado en la actualidad en Italia con una frecuencia de 42 períodos por segundo, con relación a su funcionamiento cuando la frecuencia es aumentada hasta 50 períodos. Para estas investigaciones se ha escogido la turbina Francis debido a que las turbinas de hélice funcionan satisfactoriamente a velocidades diferentes; también son de una eficiencia más elevada bajo condiciones de salto variables.

IN a paper on propeller and Kaplan turbines published in the Italian technical journal *L'Energia Elettrica* (March 1948), the author emphasized the importance of referring to the characteristic diagrams of water turbines in order to predict the degree of exactness to be expected from the use of statistical curves given by different authors when dealing with the design of these turbines. (See the work of Belluzzo, Büchi, Medici, Voetsch). Here he deals particularly with Francis turbines—machines in which water flows round a spiral casing inwardly through the wheel on a series of blades, thus developing both its kinetic and potential energy, and out to the tailrace through a draught tube. Francis turbines are used principally for medium heads.

It is proposed to utilize the characteristic diagrams in order to predict the performance of the type of Francis turbines now employed in Italy on a frequency of 42 cycles per second, in relation to their performance when the frequency is raised to 50 cycles. The Francis turbine has been chosen for these investigations because propeller turbines are known to work well at different speeds; they also have a higher efficiency under variable head conditions. Pelton turbines do not allow for considerable frequency variations.

Forecasting the performance at 50 cycles of turbines now working on 42 cycles would be much easier if the performance curves at variable speed were available. Unfortunately these diagrams are not often at the designer's disposal, because relatively small use is made of laboratory turbine models and the difficulties encountered in obtaining performance curves from full-scale plant. Moreover a turbine is not always working at its best rotational speed.

If the actual turbine speed at 42 cycles is something less than the optimum speed, the rise to a speed corresponding to 50 cycles (a frequency variation of 15 per cent.) will make no practical variation in the efficiency of the turbine. On the other hand if the turbine works normally in the zone of the diagram which is near that of decreasing efficiencies the alternation to 50 cycle running would produce a very pronounced fall in efficiency.

Mr. Novelli, the chief engineer of *Costruzioni Meccaniche* Riva, Milan, stated in a recent address to the A.E.I.—"Without sacrificing one single drop of water now employed on the existing power plants and without using one single drop of water for new plants, we may bring into being a very powerful new force of generating plant in Italy merely by improving the turbine efficiency, and by substituting new turbines of improved design for the older models at present in service." It is obvious that this is technically most attractive and is economically convenient as well, but only if the increase in efficiency meets the investment costs for new turbine plant. In those cases where the decrease in efficiency with the change in frequency is small it would be preferable to utilize the existing turbines, and researches now in progress will, it is hoped, provide the means to offset this decrease in efficiency.

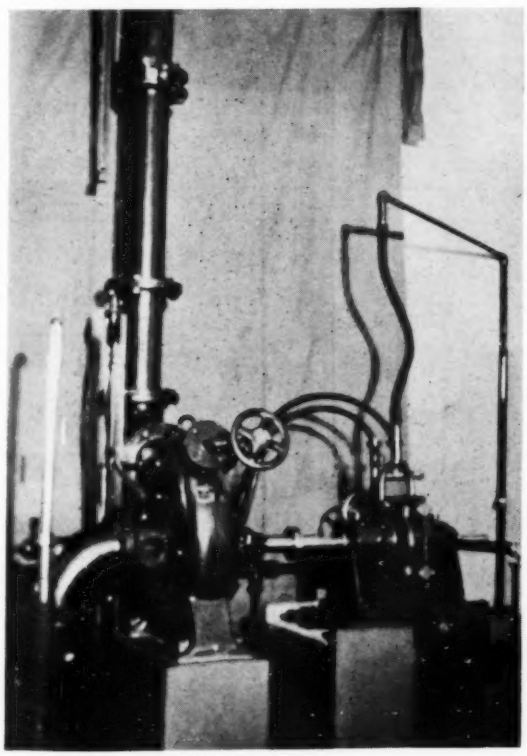
We will now consider the design data and the characteristic performances of the turbine. If the speed and the capacity are given, then a given turbine can operate with the same water only under one head with one definite efficiency. Other operating characteristics, such as power and shaft torque, can then be determined. The four variables that are sufficient to describe the performance of a Francis type turbine are not physically independent of each other. The action of the turbine under these conditions is characteristic for that particular turbine, and for its form of design. Any fixed value of Specific Speed describes a combination of operation conditions; but this inter-relation of the operating characteristics is true only as long

as there are no significant changes in the physical properties of the water relative to the forces acting in the turbine, such as viscosity and cavitation effects.

For turbines of high specific speed the rise in frequency causes an increase in the r.p.m. and a rise in the capacity of the machine; both these factors encourage an increase in the specific speed, which might alter the cavitation phenomena and its destructive effects. There may also be a lowering of the turbine efficiency. A cavitation-parameter of well known application is Thoma's ratio σ; that is, the ratio between the total head at the point where suction head is measured and the turbine-head. It has been used for over 20 years for representing the cavitation characteristics of water turbines. The increase of the σ value in the diagram in the direction of increasing specific speed indicates that for the same form of installation the turbine head must decrease with an increase in specific speed. A safer method of determination requires detailed investigation of the behaviour of the blade, and of the operating data in regard to the draught tube.

The first step is taken by controlling the dimensional and operating characteristics of the turbine; the second by checking the plant's characteristics. We analyse first the curves describing the change in the performance of a Francis turbine as a function of either the gate opening or of the rate of through flow at different speeds of rotation. These curves are called the "characteristic curves." We also make simultaneous reference to the design data. In a paper to be

Fig. 1: Testing plant for a Francis turbine in the Machinery Laboratories of the University at Padua (Italy)



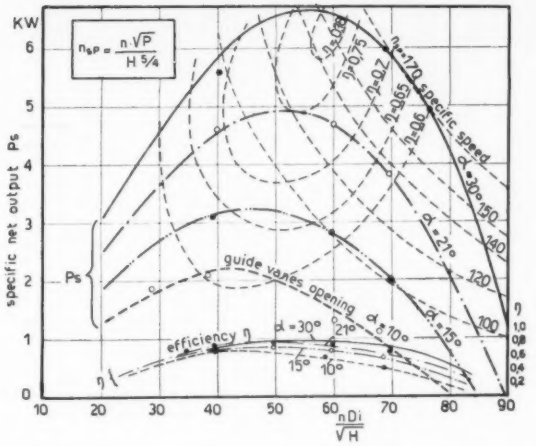


Fig. 2: Diagram with the curves of specific power outputs by different guide vanes openings at various speed of rotation

prepared we propose to apply the reverse procedure —i.e. to start from the known dimensions of an existing turbine, and to deduce its performance.

The Francis turbine we proposed to consider has the following operating data:—

HEAD	H = 8.75 metres.
CAPACITY	Q = 48 l/s (litres per second).
R.P.M.	M = 1080.
SHAFT POWER	P = 4.2 h.p.

The specific speed is:

(a) referred to the capacity $n_{sQ} = 46.5$.

(b) referred to the power output $n_{sP} = 146$.

From the operating characteristic curves of this turbine we have deduced the specific methods shown in Fig. 2, which gives us the opportunity to draw the curves of equal efficiency, and the curves of equal specific speed n_{sP}. For the turbine in question a curve of n_{sP} which corresponds to the highest efficiency is that of $n_{sP} = 146$, and this value corresponds with the turbine maker's data.

The statistical diagrams by the authors already mentioned show that for a Francis type turbine, similar to the machine in question, there should be a coefficient for the outlet specific peripheral speed of about 0.65.

Our turbine (Fig. 3) has the following dimensions:—

$D_1 = 172$ mm; $D_2 = 150$ mm; $B = 31.6$ mm.

For the case where $D_1 = 1$ m, and $H = 1$ m, the so-called "specific turbine" must have:—

$D_{2s} = 870$ mm, and $B_s = 184$ mm.

The specific speed of the turbine, which corresponds to the highest efficiency (Fig. 4) is $n_s = 55$ and the corresponding outlet peripheral speed is given by the formula:—

$$u_{2s} = \frac{\pi D_{2s}\, n_s}{\sqrt{2\, g\, H.60}} = \frac{3.14 \times 0.87 \times 55}{4.46 \times 1 \times 60} = 0.65$$

This value corresponds exactly to that given by the statistical diagrams.

The inlet peripheral speed is:—

$$u_{1s} = u_{2s}\, \frac{D_{1s}}{D_{2s}} = 0.65 \,.\, \frac{1}{0.87} = 0.74.$$

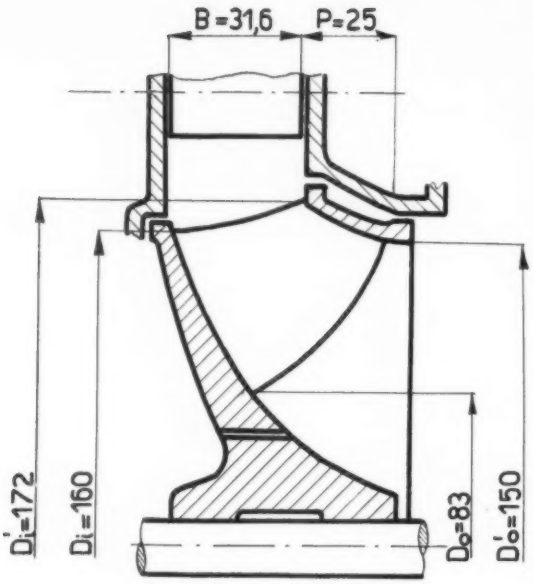
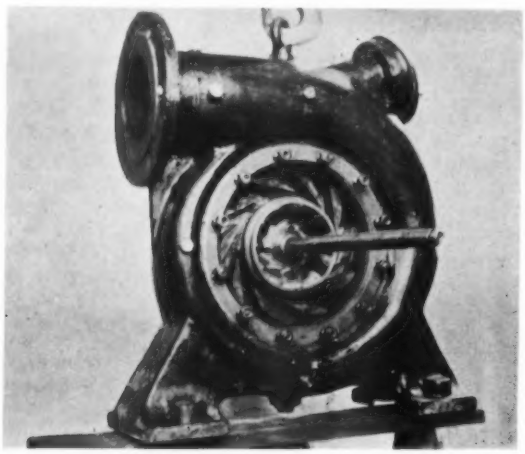


Fig. 3(a) (above): The principal dimensions of the experimental Francis turbine
Fig. 3(b) (below): A photograph of the turbine



This value is very near to that given by Medici's statistical diagrams, and is to be verified for the ratio B/D.

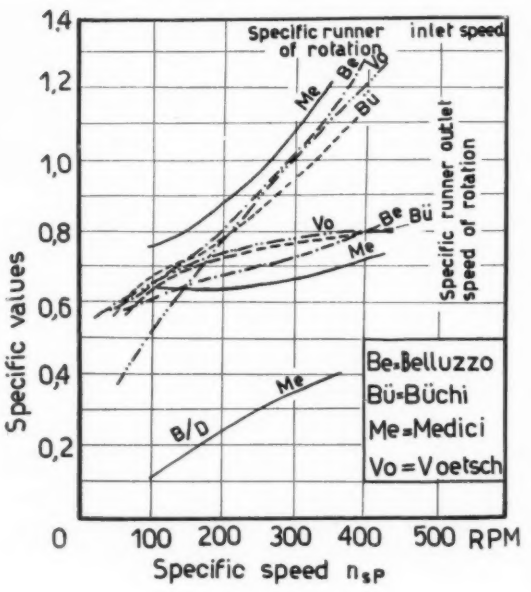
The curves taken at different speeds open up the possibility of verifying the exactness of statistical diagrams. Moreover, they bring us some useful data about the best utilisation characteristics for water turbines. The diagrams in Fig. 2 show that at increasing capacities the turbine's best efficiency point is displaced towards a higher rate of r.p.m. Under increased frequency conditions it is convenient to let an existing Francis turbine work at its largest capacity in relation to the base load. Peak loads can be met in a better way by new turbines specifically designed for this purpose, and proportioned to the new frequency.

The specific curves shown in Fig. 5 (the relationship between $Q_s - n_s$) demonstrate the mutual correspondence between the two values $n_{sP} = 146$, and $n_{sQ} = 46.5$ of the specific speed, when the first number is referred to the net turbine output and the second to the turbine capacity. They indicate that the turbine's capacity at different openings of the guide vanes diminishes with increasing speed of rotation, and the capacities tend towards one point of the diagram whose abscissa n is a positive one. The examination of the curves in the diagram, which give the turbine's net outputs at variable speeds of rotation, shows that according to fundamental similarity considerations we may derive from these curves the turbine's characteristic diagram at variable head. This diagram is extremely important in relation to performance at variable head, and of the machine's behaviour at variable speeds of rotation.

We have tested an experimental Francis turbine in a closed circuit in the laboratory of the Machinery Institute of the University of Padua, and derived the curve shown in Fig. 6 by the use of different guide vane openings. The best efficiency points correspond on the diagram to heads H, which are decreasing at increasing capacities Q. This fact conforms with the observations noted by the examination of the turbine's performance at variable speed of rotation, and was something which had been foreseen. Since in all hydro-dynamic machines there exist well known proportionality relations between the absolute and the peripheral velocity, and between the speed of rotation n and the head H, it follows that every increase of n at constant H must correspond with another operating condition relating to a decrease of H at constant n.

The H/Q-curves deduced by a recalculation from the diagrams taken at variable speed of rotation, experimentally determined by testing the turbine at variable head, confirm the possibility of utilising the same turbine for increased frequency conditions. This method of investigation, first introduced by Bergeron

Fig. 4: A proportioning diagram of the turbine for various specific speeds



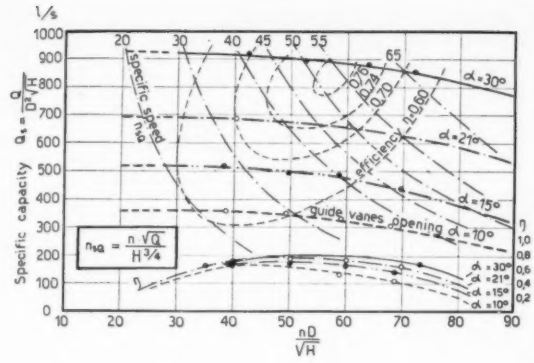
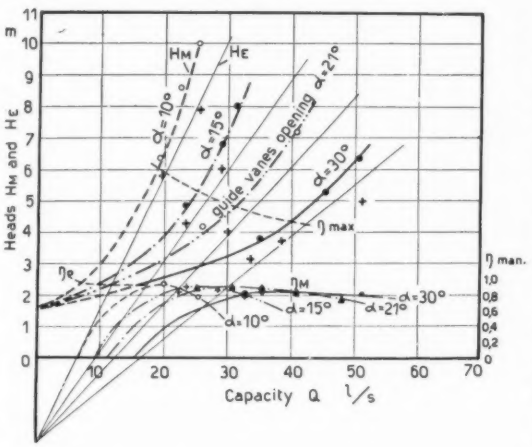


Fig. 5 (above): Diagram with the curves of specific capacities by different guide vanes openings at various speed of rotation

Fig. 6 (below): Diagram with the curves of the heads H_m and of the efficacious heads H_e by different guide vanes openings at various capacities



in the field of centrifugal pumps, and then applied by Tenot to water turbines, is a very practicable one. We do not propose to analyse its procedure; it is simply necessary to remember that an analysis as indicated by Bergeron and Tenot of the performance curves of a hydro-dynamic machine entails consideration of its manometric efficiency.

Applying this method to the experimental Francis turbine (Fig. 6) we have drawn curves of the experimental heads H, the curves of the efficacious heads H_e, the manometric efficiency curves η_M and the curve of the highest speed of rotation n_{max}. We have obtained by this procedure an inlet runner diameter which corresponds exactly to the value assigned to it by the turbine manufacturer, and an outlet runner diameter which is very near to that given by the designer. The turbine in question is, therefore, well proportioned; and it has, in fact, given efficient results, particularly in relation to its small net output, which is about 3 kW. We note, however, that the head-curves aim at a point on the diagram with a positive H_m-value, just as the capacity-curves aim at one point on the same diagram with a positive n-value. This is due to the mutual correspondence between the heads H and the speed of rotation n, as indicated previously.

We may conclude:—

1. That the statistical diagrams on Francis turbines give very valuable information about the design and performance of these machines.
2. Use of these diagrams allows an approximate prediction of the performance of a turbine at higher speeds of rotation due to increased network frequency.
3. The examination of the H/Q_M characteristic curves of the turbine gives us a fair possibility of establishing its best performance.
4. Reference to the H/Q_M diagram is particularly useful in those cases where it is desired to improve the performance of a given turbine.

AEROFOIL THEORY APPLIED TO KAPLAN BLADES

The last twenty years have seen such progress in the performance of Kaplan turbines that now the main field for improvement is no longer in increasing efficiency but rather in reducing the size of individual units and in raising the working heads. Already Kaplan turbines have ousted Francis machines for many jobs; there are several units running at heads of 100—150 feet and others are being built for heads up to 240 feet.

With this introduction Mr. S. P. Hutton, M.Eng. (Senior Scientific Officer, Fluid Dynamics Division, Mechanical Engineering Research Organisation, Department of Scientific and Industrial Research), presented his paper on the subject of "Aerofoil Theory applied to the design of Kaplan Turbine Blades," at an extra general meeting of the Institution of Mechanical Engineers held in London.

Both the reduction in size and the increase in the working head of such units necessitate minimum local velocities in order to avoid cavitation. The problem of minimising velocities round the blades for particular working conditions also confronts high speed aircraft designers, and the author discussed the possibility of the application of analagous methods to evolve blade sections for Kaplan turbines.

The distribution of velocity round an aerofoil of particular shape can be calculated, or conversely the shape of section to give a particular velocity distribution can be determined. It is therefore possible, having decided on the maximum velocity in a water turbine, to calculate a family of blade sections, none of which will cause the local velocities to exceed the selected values.

As far as can be seen from published work, the agreement between experiment and theory is not good and until more systematic experimental work is done it is impossible to decide which method of design is most reliable.

The author stated in conclusion that in general the principle of designing a blade section to give a particular velocity distribution under working conditions was a good one and provided a powerful method of attack on the cavitation problem. There was an urgent need, however, to make design methods as simple and rapid as possible and he suggested that the thin aerofoil theory might be developed for the purpose.

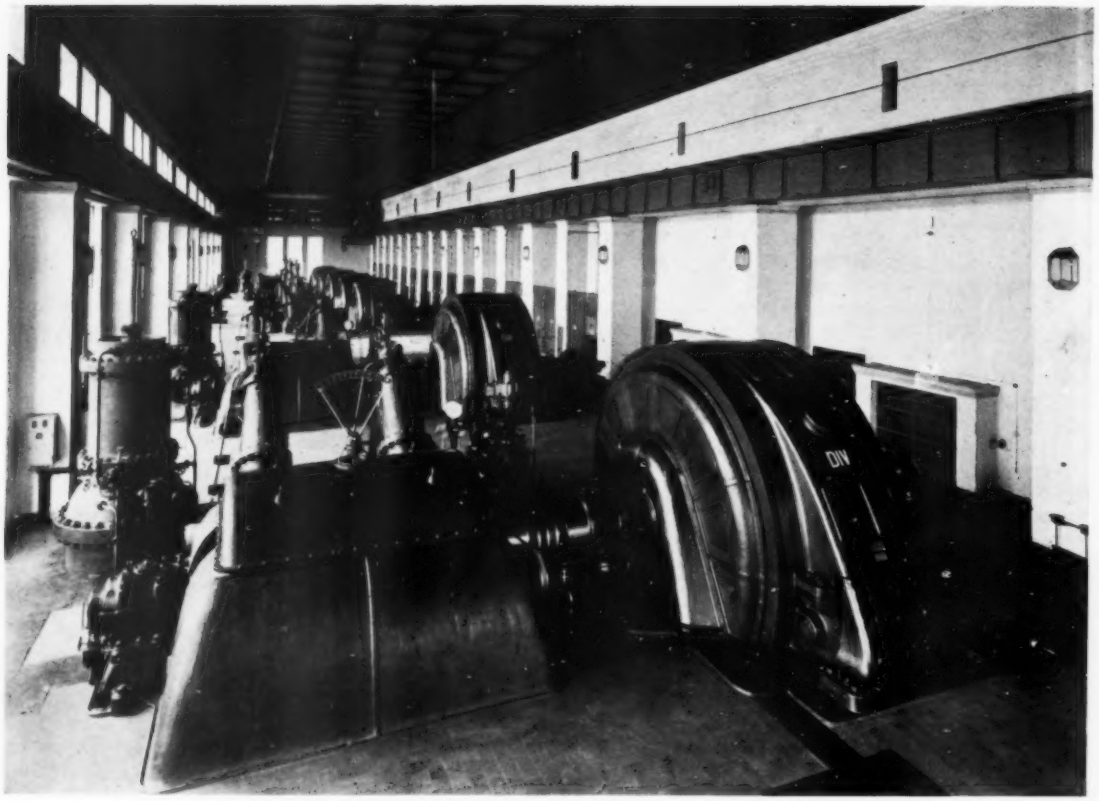


Fig. 1: Engine room of Achensee power station at Jenbach

Water Power in Austria

A survey of hydro-electric resources by Dipl. Ing. ROBERT STEINER, manager of the Tyrol Hydro-Electric Power Company, Innsbruck.

OF the Central European countries, Austria undoubtedly has the most water power within its frontiers. In this region, which is traversed by the main ridge of the Alps, the two western provinces of Vorarlberg and Tyrol possess the greatest wealth of natural resources; it is not surprising therefore to find that twenty-five years ago these two provinces commenced the development of large-scale water power in Vorarlberg on the Ill, by the Vorarlberger Wasserkraftwerke A.G., Bregenz, and in the Tyrol by the Tiroler Wasserkraftwerke A.G., Innsbruck. These concerns established the first large reservoirs—the Illwerke's Silvretta reservoir, with an effective capacity of 31 million m^3, while the Tiroler Wasserkraftwerke A.G. made use of the natural basin of the Achensee Lake, which can be lowered to 11 metres so that 70 million cubic metres of water can be utilised.

The Vorarlberger Illwerke has at present three works in operation—Parthennen, Rodund and Obervermunt, with a total output of 280 MW and an annual production of 570 million kWh. With the exception of the small amount of energy consumed in the small province of Vorarlberg, the total production passes over the 220 kV line running into Germany as far as the Rhineland.

The Tiroler Wasserkraftwerke also supplies a large portion of the energy generated at its oldest works, the Achensee station, to Germany, over a 110 kV line via Scharnitz-Mittewald to Kochel and as far as the Walchensee power station of Bayernwerke AG.

The Achensee power station works with a head of 400 m, for the level of the Achensee is this much higher than the valley of the Inn. The power station is at Jenbach, to which the water is taken by a pressure tunnel 4.6 km long and a pressure shaft 0.5 km long. The volume of water used is 28 m^3/sec. The power station contains four alternators, two of 13,000 kW each, two of 25,000 kW each, and three single phase units of 5,000 kW each for supplying the federal rail-

Fig. 2: Forebay reservoir of the power station Bösdornau near Mayerhofen in Zillertal

Fig. 3: Engine room of power station at Bösdornau near Mayerhofen in Zillertal

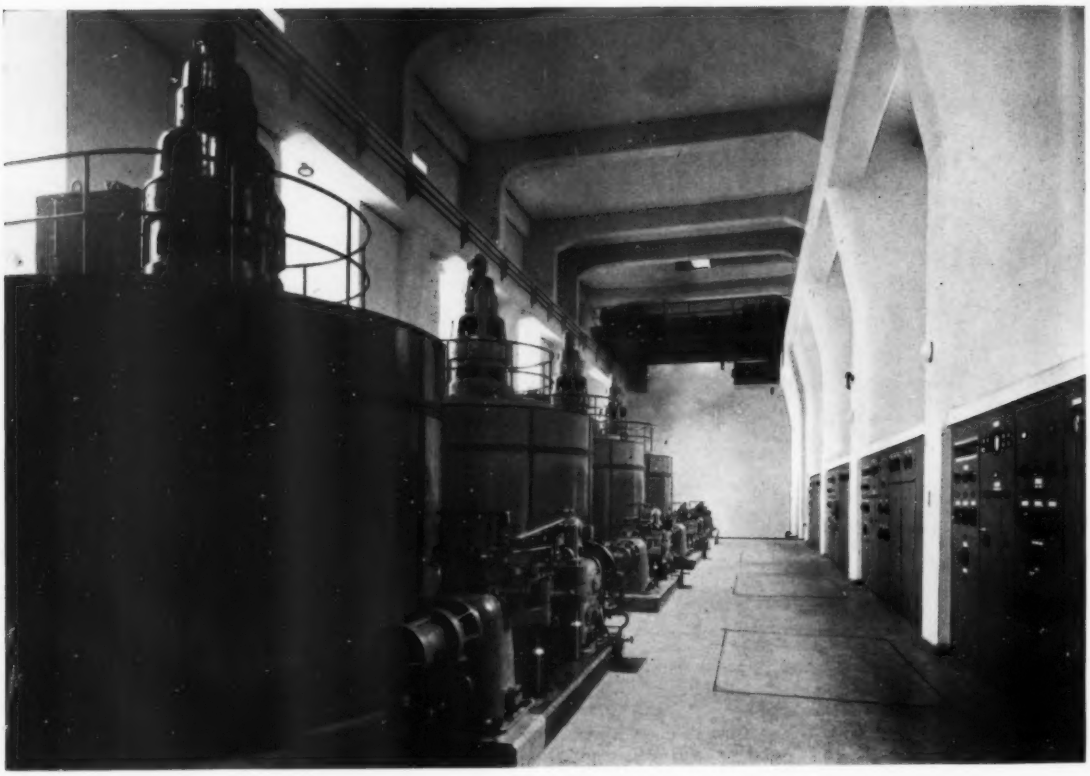


Fig. 4: Engine room of Gerlos power station at Zell. a. Ziller, Zillertal

Fig. 5: Kirchbichl power station, general view

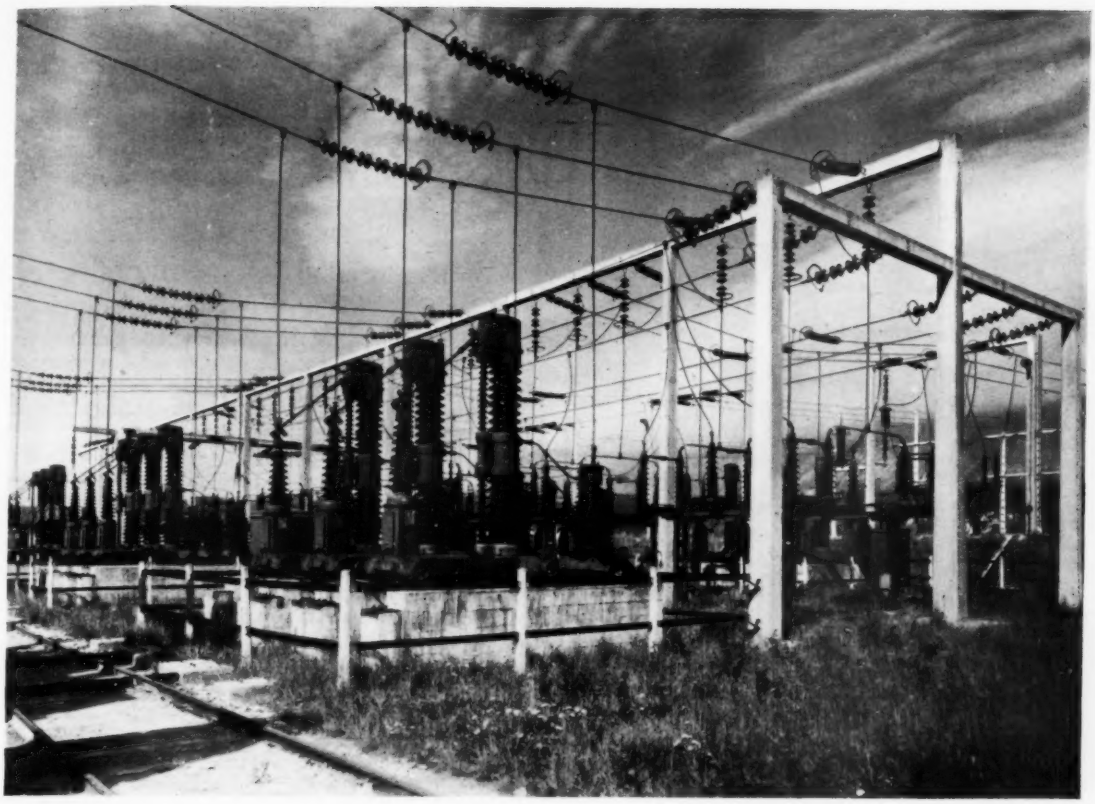


Fig. 6: 110 kV open air switchgear of power station, Kirchbichl

way (Fig. 1). The annual output is 200 million kWh, including 120 million in winter.

A second power station is owned by the Tiroler Wasserkraftwerke in the Zillertal valley, above Mayerhofen. This is the confluence of the supply streams of the Ziller, Tux, Zem and Stillupbach, and by means of short tunnels the first two are taken to a water chamber situated 200 m. above the station (Fig. 2), from which the village of Mayerhofen and the beautiful girdle of the mountains are visible.

From the water chamber a pipeline about 840 m. long, laid partly on the surface and partly underground, leads to the power station, where the volume of water used is 12 m^3/sec. In the power station there are four generators, each of 7,000 kW (two with Francis spiral and two with Pelton turbines), and a smaller local turbine with an output of 1,350 kW (Fig. 3). Through a 110 kV line this installation is connected to the Achensee works. The annual power output is 133 million kWh.

In the Zillertal there is the latest power station of the Tiroler Wasserkraftwerke, the Gerlos power station, which utilizes the 600 metre head of the Gerlos, a large tributary of the Ziller. This station possesses a small weekly reservoir (Fig. 7), formed by a 37 m. high arched wall (the first in Austria). A pressure tunnel about 6 km. long and a pressure shaft 1,400 m. long bring the water at the rate of 12 m^3/sec. to the power station, which contains four vertical Pelton turbines, each with an output of 18,750 kW (Fig. 4). The annual production is 240 million kWh, which is taken by a 110 kV line in an easterly direction via Kaprun to the Austrian load centres.

There is also a low-pressure plant in Austria, at Kirchbichl on the Inn, where a great loop in that river is intersected by a canal about 1 km. long. A head of about 9 m. can be utilised, with a flow of 250 m^3/sec. (Fig. 5). The power station contains two Kaplan turbine units of 9,000 kW each, and one of 4,500 kW. Annual production of energy is 110 million kWh.

An open air switchgear station (Fig. 6) connects the station to the 110 kV double line which passes close by and connects the Achensee station, via Kufstein-Rosenheim, with the Bavarian power station. Besides these power stations which are already in operation there are a number of installations in process of erection.

Mention must be made of the large reservoir station of Grossglockner-Kaprun, which in two stages of 800 m. and 400 m. heads makes use of the water of the Grossglockner area during thaws. The Kaprun power station has already been completed and is in operation with two units each of 50,000 kW; two further units each of 60,000 kW are on order. On completion of the two large reservoirs at Limberg, now under construction, with capacities of 85 million m^3 and 68 million m^3, this installation will have an annual output of 600 million kWh, including 400 million kWh in winter.

Further to the east there is another group of power stations under construction, including Grossraming,

Fig. 7: Arched dam of Gerlos power station at Gerlos Zillertal

Ternberg, Mülrading and Stanning; some are already in operation. On completion of the machinery equipment these stations will have an energy production of 700 million kWh.

To the south of the main ridge of the Alps, on the Drau, two power stations were erected during the war: Schwabeck, with a dam 21 m. high in the river

No.	River area	No. of stages	Capacity mill. m^3	Total output MW	Total energy kWh mill.
1	Bregenzer Ache	6	510	612	1,000
2	Ill - - -	15	239	712	1,950
3	Inn - - -	4	100	392	1,340
4	Otztaler Ache -	4	192	723	1,430
5	Isel - - -	5	310	440	1,010
6	Danube - -	1	—	153	995

and Lavamünd. The former has an output of 60,000 kW and the latter 22,000 kW. The annual output of both works totals 500 million kWh, which is conveyed to Vienna by a 110 kV line through Styria and Semmering.

Many more schemes are proposed; but the figure of 40 billion kWh stated by many planners to be the ultimate development in Austria is regarded as an exaggeration—25 billion kWh would be reasonable. At present about 6 billion kWh are being consumed in Austria, both from hydro-electric and steam stations. Even in the event of a great increase in its own consumption of energy in the next few decades Austria should, however, be able to export 10 to 15 billion kWh, to the neighbouring states of Germany, Italy or Switzerland, if needed.

Austria is a poor country and unable to finance the development of hydro-electric projects; she is, however, prepared to make her natural resources available for development on advantageous terms.

The accompanying table refers to projects that have been planned and are ready for execution in a short time, provided the requisite funds are made available.

HYDRO-ELECTRIC PROJECTS IN GREECE

In a determined effort to promote the economic rehabilitation of Greece, for which the development of electric power is essential, plans were put in preparation at the time when Marshall Aid first began two years ago. This work was entrusted to the Ministry of Co-ordination which was assisted by the services of suitable experts who freely placed their knowledge and experience at the disposal of the Government. As a result of a preliminary survey it was possible to formulate a plan and it is on this plan that the present long-term programme is primarily based. During the past year an American company, Ebasco Services Inc. have been investigating the situation and have confirmed that the original survey was on sound lines from both the economic and technical points of view. Backing for the programme cannot, however, be met from Marshall Aid funds until a more complete assessment has been made but it is understood that Ebasco Services Inc. have recommended the construction of three hydro-electric stations on the Vodas, Ladhon and Acheloös rivers and a thermal station near Chalkis, together with a high-tension network system to distribute the current over the whole country. This recommendation envisages the commencement of work on all these projects simultaneously and it estimated that they will be completed about 1955. Arrangements have already been made with Italian interests to construct the Vodas and Ladhon plants on a reparations basis and work will begin as soon as approval has been received from Washington.

The construction of these stations will be accompanied by the erection of high-tension transmission lines to Athens and to Salonika and to form a direct connection between these two cities. A new local distribution network is envisaged for Salonika and the Athens system will be greatly extended and improved. A number of small local plants will contribute energy to the main distributing systems.

It is hoped that sufficient finance will be available to enable a substantial part of this programme to be completed by June, 1952. Some $66.6 million of foreign exchange is anticipated to be available by this date and 419,400 million drachmae. In accordance with the Ebasco report, however, the total cost of the final programme will amount to $96.1 million in foreign exchange and 1,749,000 million drachmae. These figures include the cost of completing the Acheloös (Kremasta) and Louros power stations together with their respective transmission lines. Foreign exchange to the tune of $66.6 million is expected to be provided by E.R.P. aid and out of funds derived from the Greek-Italian Agreement of Economic Co-operation.

Developments in Canada

A REPORT ON PROGRESS IN 1949

IN the field of hydro-electric progress in Canada 1949 was a year of development in projects already established to a greater or less extent. The post-war boom in construction has continued unabated, as is made clear in the survey of the Dominion Water and Power Bureau of the Canadian Department of Mines and Resources. No new plants of any great size came into operation, but total installed capacity was increased by new units completed at existing stations—a phase of development particularly favoured by the availability of materials and labour.

The increase in installed capacity achieved was 479,000 h.p., bringing the grand total for the Dominion to 11,622,668 h.p., including the 272,050 h.p. of the new province of Newfoundland. This increase exceeds by a small h.p. that of 1948, but is well in excess of the pre-war yearly rate of expansion. Of its urgent necessity there can be no doubt, for general industrial development brought about an increasing demand for consumption of power — commercial, domestic and rural. The consumption of primary power during the first ten months of the year went up by 3.1 per cent. over that for the comparable period of 1948 (itself a high record) and 12.9 per cent. over 1947.

The output of central stations, however, was only 2.8 per cent. greater than for 1947; this is explained for the most part by the unfavourable stream flow conditions during the greater part of 1949. The situation, with its attendant difficulties in meeting all demands, served to reveal the need still existing for establishing an essential reserve capacity which can come only with the completion of some of the larger plants now envisaged.

British Columbia heads the provinces in actual additions to installed water power capacity for the year, with a total of 228,300 h.p. A single addition accounted for 124,000 h.p. in two new units (62,000 h.p. each) in the Bridge River plant of the British Columbia Electric Railway Company, which brings present plant capacity to 186,000 h.p. This plant has been designed for an ultimate installation of ten units. The company also has in hand a third unit of 47,000 h.p. for operation this year, including an extension to the power house and a new penstock tunnel and tunnel intake, at its Ruskin Plant on the Stave River.

At Jones Lake, roughly 80 miles east of Vancouver, investigations are proceeding that will lead to a development of about 70,000 h.p. under a head of 2,000 feet, while in power distribution a big programme of sub-station construction was carried through in Vancouver, the Fraser Valley, and on Vancouver Island. On the island a double-circuit 132 kV transmission line is being built to tie in at Nanaimo with the British Columbia Power Commission's system.

At the John Hart development of the same commission on the Campbell River, Vancouver Island, two more units—the third and fourth, of 28,000 h.p. each were put into operation and it is possible that a fifth unit may be added. Work has been continued on the Whatshan Lake project in the south-central part of the province and the plant, with an initial installation of 30,000 h.p. in two units (ultimately to be increased to four) is expected to be brought into operation late this year. On the Kootenay River the Consolidated Mining and Smelting Company of Canada completed the installation of a third 37,000 h.p. turbine in its Brilliant plant, and there have been several other smaller additions to plant.

The Aluminium Company of Canada continued its investigations with the object of providing a high-head plant of large capacity on one of the coast inlets by diverting Fraser River water through a tunnel driven under the Coast Range. Surveys were made of dam sites and transmission line routes, and an examination of the power resources of the entire Fraser River basin were undertaken by the Water Rights branch of the province. River basin engineering studies covering the Columbia River in Canada were carried out by the Dominion Water and Power Bureau on behalf of the International Joint Commission, complementary to similar studies on the river in the United States by Federal authorities.

Ontario has so much in hand in the hydro-electric field that it is not surprising the Hydro-electric Power Commission of the province did not bring any new units into operation during the year. Concentration was rather on the furtherance of the tremendous programme already mapped out. At the Des Joachims site, some 40 miles above Pembroke on the Ottawa River, the construction of the main dam is approaching completion, a portion of the power house has been erected and further work was done on assembling the turbines, erecting of penstocks and excavating the tailrace. This station will comprise eight units of 60,000 h.p. each. Three of these, it is expected, will be in operation during the coming summer and the rest in the autumn or early in 1951.

The Chenaux development is now well advanced. This includes a main dam and powerhouse, dams on Limerick Island, the Portage du Fort channel and a side dam on the east shore, totalling in all about 5,000 feet. The station will consist of eight units of 20,000 h.p. each. Two should be ready for operation by the end of the year and the rest next year. A third Ottawa River site, Le Cave, a few miles above Mattawa, was under active construction during 1949. Here the dam will be 2,500 feet long and the river will be backed about 40 miles extending upstream to Lake Temiskaming. The six units will be of 32,000 h.p. each, and there will be provision for two additional units. The

Fig. 1: Airview of the Bonneville Dam (Oregon) in Columbia River Valley

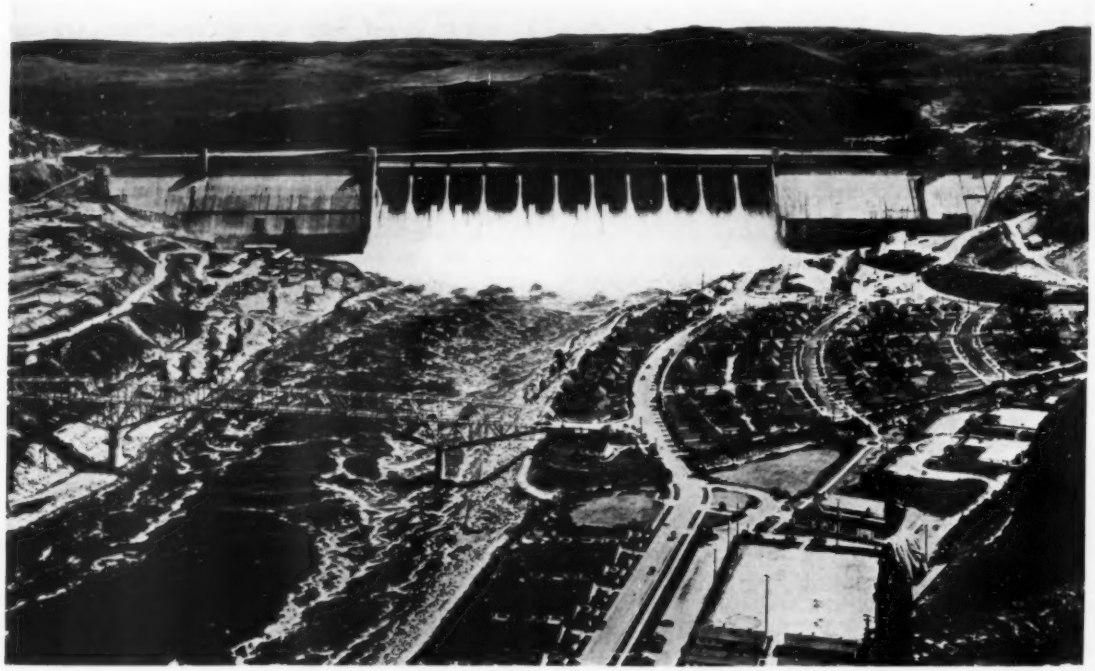


Fig. 2: Grand Coulee Dam, Washington, which is 550 feet high, 4,300 feet long, and contains 11,250 cubic yards of concrete

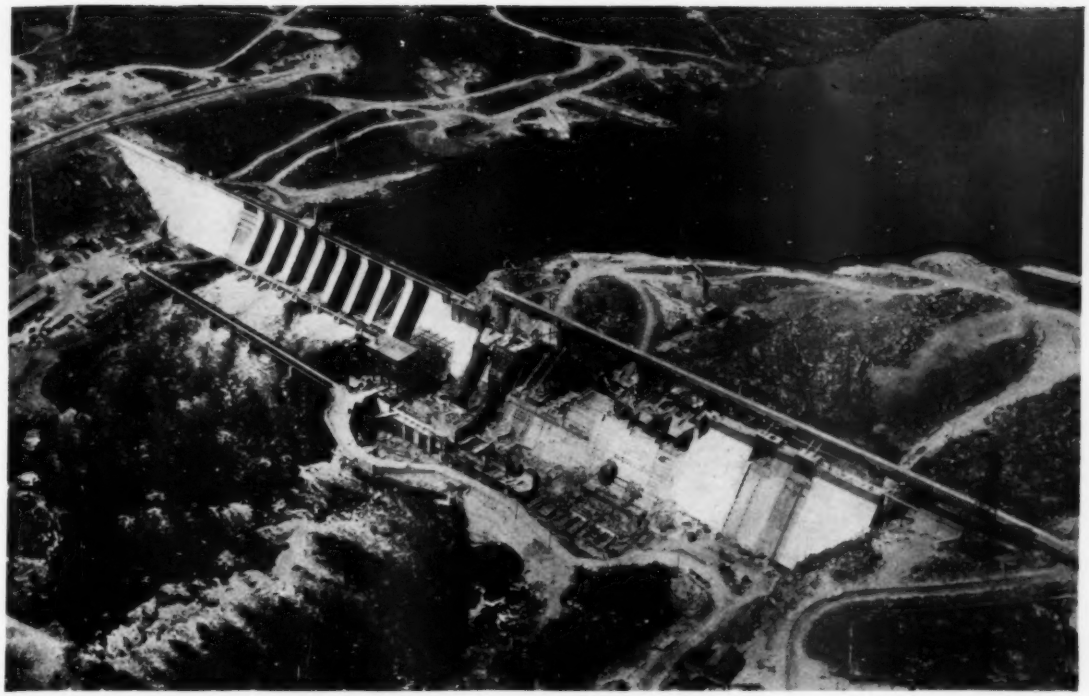


Fig. 3: The Des Joachim Hydro Power Plant (Ontario)

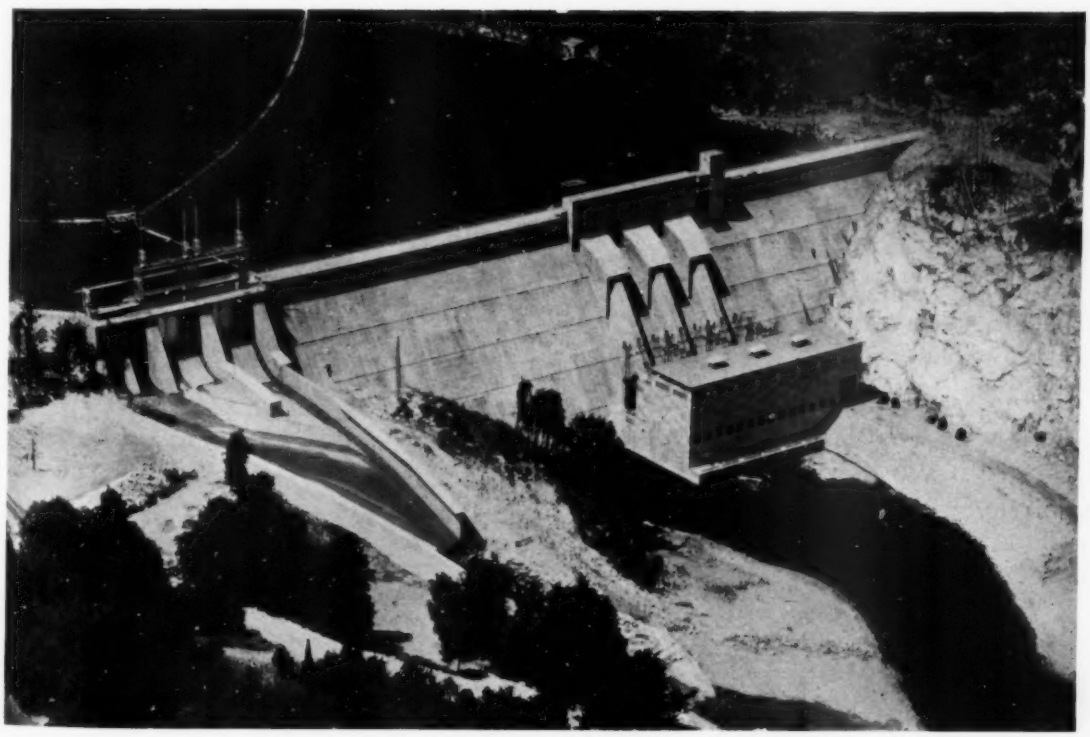


Fig. 4: The Stewartville Hydro Power Plant (Ontario)

Fig. 5: The power house at the Kootenay River plant, British Columbia

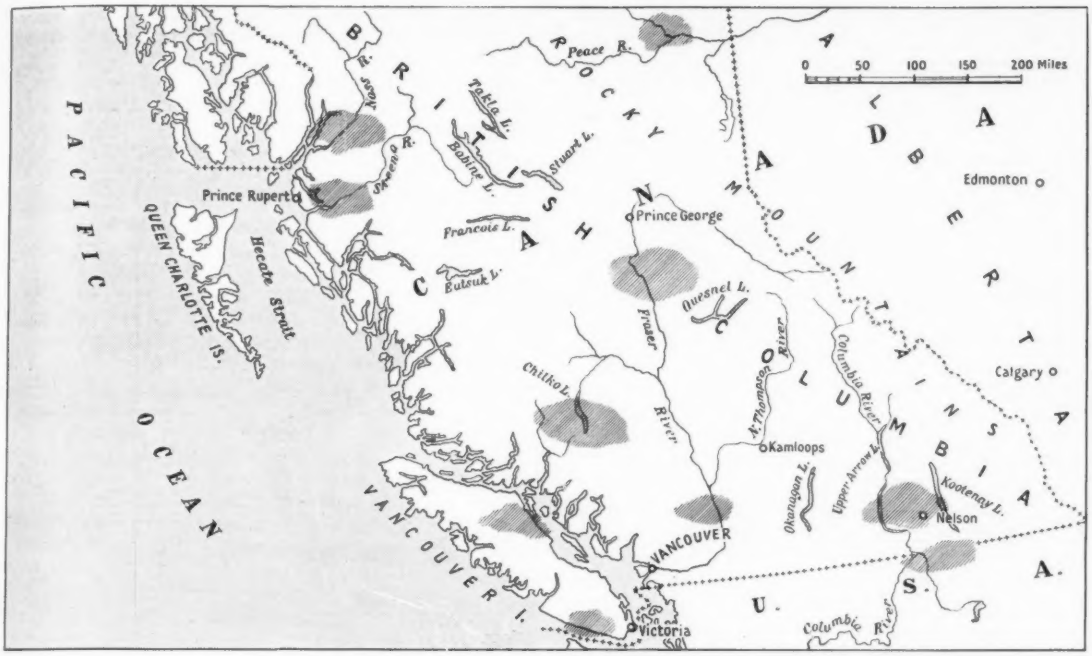


Fig. 6: Map of British Columbia showing hydro-electric development areas (shaded)

Fig. 7: Barretts Chute, Ontario Hydro Scheme

first unit is scheduled for service early in 1952, and the others at about two-monthly intervals.

Great progress has been made on the Pine Portage project on the Nipigon River, which is to have an initial installation of two units each of 40,000 h.p.; these are planned to be put into operation this summer. There is provision for two additional units of similar capacity. On the Mississagi River, in the neighbourhood of Thessalon, a high dam at the Tunnel development site is now virtually completed. Excavation for the main dam, side dam and sluiceways is finished, and construction of the log chute and tailrace are now under way. Two units, each of 28,000 h.p. are to be installed here, and it is hoped that the station will be in service before the end of the summer. The Rocky Island Lake storage dam, upstream of the Tunnel on the Mississagi River and associated with the Tunnel development also is practically completed.

The Power Commission's high voltage network was extended during the year by 352 miles of 230 kV line and 12 miles of 115 kV line; 240 miles of secondary lines (13.2 to 44 kV) and 4,600 miles of rural lines. About 37,000 new rural consumers were connected to the system during the past year. Other important work apart from that of the Power Commission has been going steadily forward. The Great Lakes Power Company reports an increased capacity of 2,300 h.p. at its plant at the Upper Falls, Montreal River, as a result of the raising of the dam in 1948.

A new 13,200 h.p. unit is also to be installed in the company's plant on the Michipicoten River for operation this year, and the town of Orillia has under construction a new development of 3,750 h.p. on the south branch of the Muskoka River near Mathiasville.

Of the province of Quebec's 190,000 h.p. additional hydraulic installations the major part was for the Shawinigan Water and Power Company, which completed its works at the Shawinigan Falls on the St. Maurice River by bringing into operation the second and third units of 65,000 h.p. each, total plant capacity now being 195,000 h.p. At La Trenche Rapids, which will have an ultimate capacity of 390,000 h.p., the cofferdams in the main St. Maurice River have been finished and the river flow diverted through a bypass channel. It is anticipated that the first unit will be in operation here early next year. Expansion of transmission and distribution systems was continued by building 82 miles of high voltage lines and 1,300 miles of rural lines, and at the close of 1949 about 40,000 farms were being served.

In the Quebec Hydro-Electric Commission's plant at Beauharnois on the St. Lawrence River there will be an ultimate capacity of 600,000 h.p., but present plans are for three units of 55,000 h.p. each by next year, and three additional units by 1952. In the Temiscamingue-Abitibi district the Commission, as administrator for the Government, has completed installation of a fourth unit of 16,000 h.p. in the Rapid VII Ottawa River plant, and in anticipation of expanding power demands of the area field surveys have been conducted for a development at Rapid I on the Upper Ottawa River.

The third and final unit of 27,000 h.p. in the Bryson Plant on the Ottawa River was put into service towards the end of last year by the Gatineau Power Company, water being provided for the unit by a regulating dam on the Rocher Fendu channel on the west side of Calumet Island. Similarly, the Northern Quebec Power Company increased the Quinze River plant capacity by 10,000 h.p. by completing the raising of the dam which now provides 20 feet of additional head. The present plant contains four units now rated at 12,500 h.p. each, and a fifth unit of 34,500 h.p. capacity is being installed and will be in operation soon.

Alberta, Saskatchewan and Manitoba have each continued their development programmes, that in Saskatchewan being at present limited to the northern mining areas. The Calgary Power Company made marked progress on its Spray Lake development in the Upper Bow River basin; the main storage dam at the outlet of the lake is completed and initial operation is scheduled for next October. Manitoba's total hydro capacity went up by 54,000 h.p. with the raising of the water head and installation of a new plant for the Winnipeg Electric Company at Seven Sisters Falls, on the Winnipeg River. Power house extension was completed to allow for the ultimate installation of six units of 37,500 h.p. each, while the head was raised to the final limit of 66 feet. A fourth unit has been installed and a fifth will probably be in operation by the middle of the summer.

In the maritime provinces Nova Scotia completed the doubling in size of its original plant with the 4,500 h.p. addition to the Black River plant of the Nova Scotia Light and Power Company, and a 5,000 h.p. development is in prospect for the present year on Paradise Brook. The New Brunswick Electric Power Commission has investigated several sites, in particular one of 16,000 h.p. on the Magaguadavic River; but so far no commitments have been made. Newfoundland made no new additions during the year to capacity but the Newfoundland Light and Power Company has a 13,000 h.p. scheme on the Mobile River for operation this year.

Apart from the projects mentioned here there are several others in various parts of the Dominion which will doubtless be undertaken during the next few years. There is in fact every prospect that the basic power requirements of Canada's undoubtedly expanding economy will be supplied in large measure from her enormous water power resources.

Book Review

Praktische Energiewirtshaftslehere

By Dr. Ludwig Musil. Published by Springer, Vienna (1949), 279 pp., 111 figures, 6 in. x 9 in.

While agreeing with the author that it is essential for the engineer developing any power scheme to make a scientific analysis of the factors involved, one realises that there is nothing original in the technique. A general treatise therefore, such as this work, describing the factors involved in the utilisation of all natural sources of power with the exception of atomic power, can only hope to draw a sketch of the procedure involved. It is impossible to arrive at any definite conclusions because of the local variations in conditions and prices encountered in practice.

Of the seven chapters, those on water and wind power will be of most interest to hydro-electric engineers. In the former (Chapter 3) the hydrology of Central Europe is dealt with briefly and empirically. The usual analysis of run-off storage and demand curves is made and the method of estimating power resources shown. Qualitative comparisons between dam storage, river and underground power stations are made in terms of the economical number of units to build. A brief discussion of natural and artificial pumped storage schemes is made with reference to Austria.

Wind power is treated rather sketchily in Chapter 4 and no figures for world distribution of wind or suitable areas are given, nor is any reference made to American or Scottish projects.

The economic use of coal and its byproducts is described, and the uses of heat pumps and closed heating circuits advocated for district heating. The final chapter describes the generation and distribution of electricity for the grid system.

The book is continental in its outlook and although the thirty-eight references quoted are useful they are all Austrian or German. The author, who is on the staff of the School of Technology, Graz, has produced a useful elementary text book for the student requiring a background on power resources in Europe. For the engineer, however, its scope is limited.

S.P.H.

Hydro-Electric Development in Iceland

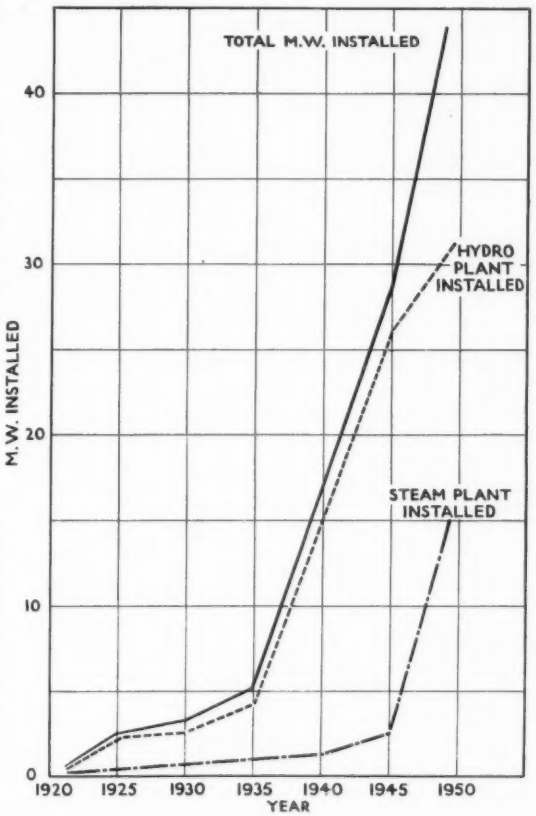
A short note on the developed and potential resources, as assessed by a British engineer during a recent visit to the country.

COVERING an area of 40,000 square miles and with a population of 140,000, Iceland has no railways, no major industries nor are there any mineral deposits worked. Though about one-fifth of the inhabitants are engaged in dairy farming the produce is used wholly in the island, and their international trade is dependent on the fishing industry.

So far no coal deposits have been found so coal and oil are both imported and cost some £15 per ton. Naturally, therefore, hydro-electric energy is the main source of power and the load is practically wholly domestic, the few fish processing factories and small workshops taking only a negligible proportion.

Until the occupation of the Island by Allied forces in 1940, the standard of life was comparatively low, but since that year, has risen considerably and with it the electricity consumption, as is shown in Figs. 1 and 2. These graphs refer to public electricity supply only; it is estimated that a large number of small diesel units in farms and remote dwellings account for another 11 MW of installed capacity and 22 million units, giving a present total installed capacity of 55 MW with a consumption of 205 million units or 1,460 units per head of population.

The principal existing hydro-electric developments are shown in Table I and Fig. 3. The Sog and Laxa rivers are both susceptible of further development. The former at the combined Ira and Kistu falls where plans are well advanced for the installation of an underground station of 31 MW capacity, the maximum for the site being 46 MW. On the Laxa the Lower Bruar scheme is also well under way, the first stage covering a single 8 MW set. Again the plant is to be underground.



The potential water power of Iceland is shown in Table II and Fig. 3. Unless, however, some major industry consuming large blocks of electrical energy is developed, there is no reason to expect that

Fig. 1 (above): MW Installed Capacity

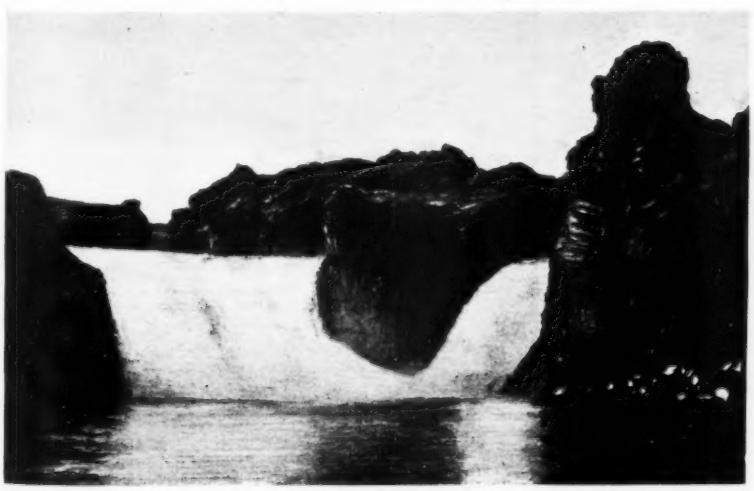


Fig. 2 (left): Hjalpar Falls

Fig. 3 (above): Potential and operating hydro-electric resources

much further expansion will take place, other than that immediately contemplated. However, geologists believe that there is a possibility of discovering mineral wealth in the east of the Island, bauxite having been suggested, and if such is the case some of the larger schemes may well come into being. It should be borne in mind that the three major rivers, which have the greatest potential power, are glacial and as such carry considerable quantities of abrasive matter. The waters of the Sog and Laxa, on the other hand, are very pure as they pass, underground, through lava beds which act as a perfect filter.

The new underground plant on the Sog is very interesting. Two falls in series are to be utilised, situated about half a mile apart, and giving a gross head of about 120 ft. A normal design would have necessi-

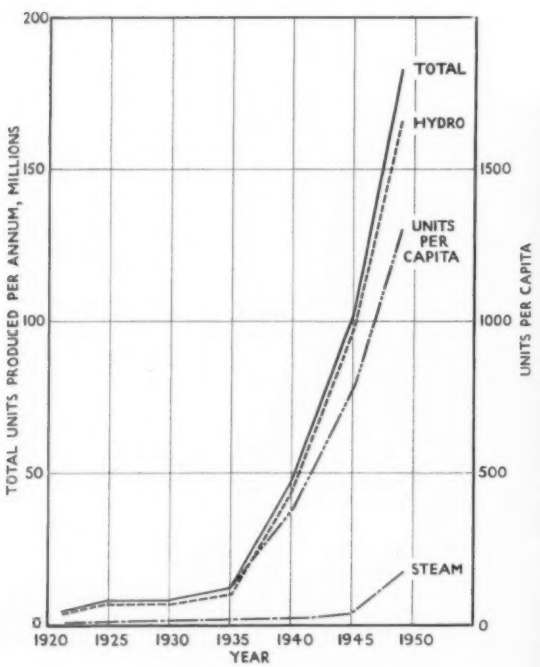


Fig. 2 (left): Total generation and consumption per capita a year

Fig. 4 (below): Oxara Falls

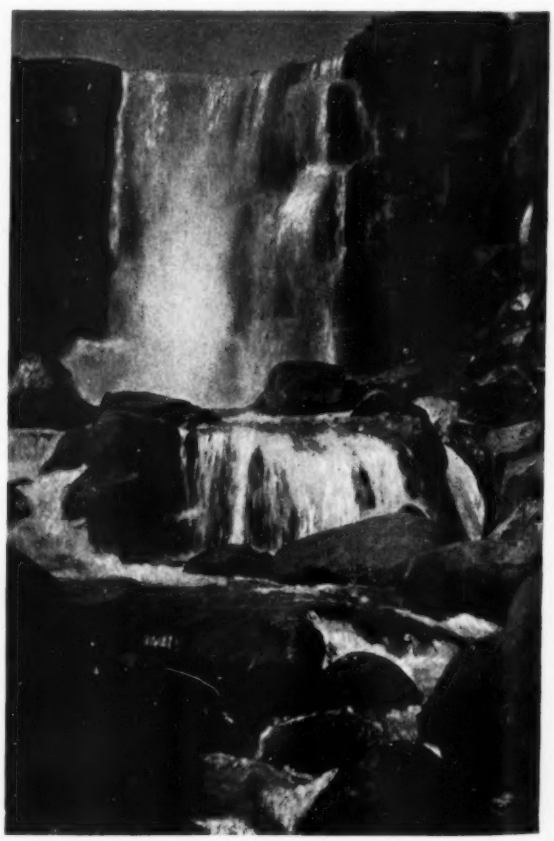


TABLE I.—PRINCIPAL EXISTING HYDRO-ELECTRIC PLANTS IN ICELAND

Plant	Installed kW
Ljosa Falls on Sog	14,500
Ellidaar (near Reykjavik	3,200
Andakilsa	3,500
Upper Bruar on Laxa	4,300
Skeid Falls	1,600
Others (under 1,500 kW)	5,900
Total	33,000

TABLE II.—MAJOR SOURCES OF POSSIBLE HYDRO-ELECTRIC POWER IN ICELAND

River	Total Potential MW Inst.	No. of Sites	Name of Site with Maximum Potential Capacity	Possible Max. MW Inst.
Thjorsa - -	450	6	Burfell - -	230
Hvita - -	200	4	Gull Falls -	110
Jukulsa a Fjollum	150	2	Detti Falls -	130
Sog - - -	95	3	Ira-Kistu Falls (under const.)	46
Laxa - - -	60	2	My vatn (Bruar) (under const.)	40
Others - -	545	—	—	—
Total - -	1,500	—	—	—
Possible annual output, kilowatt hours - - -	6,000 million	—	—	—

tated a long intake duct and the land near the lower falls was not particularly convenient for siting a station. Fortunately, near the upper falls there is a piece of land well suited for a transformer and switching station. The ground below was found to be good, sound rock and a tail water pipe only 750 yards long can be constructed to pass under the Sog so cutting off a big sweep in the river. The discharge from the turbine returns to the river again below the second falls, thus effecting a considerable saving in capital outlay.

The Uganda Scheme

From our Parliamentary Correspondent

In the House of Commons recently Mr. John Hynd asked the Secretary of State for the Colonies whether he would make a statement on the progress to date of the Uganda hydro-electric development scheme; and the prospects of the development of the various new industries that were dependent on the scheme.

Mr. James Griffiths said that the contract for the erection of a dam and hydro-electrical station at Jinja was placed in September, 1949, and preliminary work on the site had now begun. It was too early to give a detailed forecast of industrial development in the Jinja area, but prospects for the manufacture of cotton textiles, fertilisers, paper, building materials and iron and steel were among those being considered. A cement factory had already been started at Tororo, and would eventually draw its power from Jinja.

Mr. Hector McNeil, the Secretary of State for Scotland, has confirmed a scheme prepared by the North of Scotland Hydro-Electric Board for the erection of overhead transmission lines to run from Aberdeen to Dundee and link up electricity supplies in these cities.

A White Paper, issued by H.M. Stationery Office, 13A, Castle Street, Edinburgh, price 1d. net, states that this Constructional Scheme (No. 19) has been confirmed and laid before Parliament in accordance with Section 5 of the Hydro-Electric Development (Scotland) Act, 1943. The lines will run from a transforming station at Craigiebuckler, Aberdeen (now being erected under Constructional Scheme No. 11, already approved) through the counties of Aberdeen, Kincardine and Angus to an existing transforming station at Strips of Craigie, Dundee. The scheme provides for the erection of three-phrase overhead lines partly on wood poles and partly on steel towers. The estimated capital cost of the scheme is £372,000.

The Amenity Committee, who were consulted in accordance with Section 9 of the Act, did not make any recommendations on the Scheme, on the understanding that due care would be taken to ensure that the lines did not interfere with any places of historic interest.

Constructional Scheme No. 19 was approved by the Electricity Commissioners on 31st March, 1948. Thereafter it was submitted to the Secretary of State for confirmation. In accordance with the Act, public notice of its submission was given on 30th July, 1948, and subsequent dates, and the Scheme was made available for public inspection for a period of 40 days during which objections to it could be lodged with the Secretary of State. Objections were lodged against the Scheme, but were not persisted in.

Following the publication of the scheme, the Board slightly amended the route and limits of deviation of the lines to meet the views of objectors, and this amendment was approved by the British Electricity Authority on 25th January, 1950. The Amenity Committee had no observations to make on the amendment, and all the owners and occupiers of the lands within the altered limits of deviation have agreed to the alterations as affecting their lands.

The Secretary of State is satisfied that it is in the public interest that the Board should be authorised to carry out the scheme as amended, and he has accordingly made an Order, under Section 5(4) of the Act of 1943, confirming it.

The North of Scotland Hydro-Electric Board has also been given authority by the Secretary of State for Scotland to carry out another project, at an estimated cost of £491,000, for the erection of overhead transmission lines to convey electricity from a transforming station at Errochty, near Tummel Bridge (Perthshire), to a transforming station at Inveruglas (Dumbartonshire), on the west side of Loch Lomond. The lines will form a connecting link for the power supplies in the east and west of Scotland, and will later carry part of the output of further hydro-electric schemes to be developed in the area.

Mr. John Grimston asked the Secretary of State for Commonwealth Relations when agreement is expected on the timing of the scheme to generate electricity on a large scale at the Kariba Gorge on the Zambezi.

Mr. Gordon-Walker said that the Governments of Southern Rhodesia and Northern Rhodesia appointed in 1946 an Inter-Territorial Hydro-Electric Power Commission whose duties included the establishment of the necessary facts to determine whether it would be possible to obtain hydro-electric power from the Zambezi River near the Kariba Gorge. A considerable amount of hydrological data had now been collected and was being submitted to a panel of consultants, who would report to the Commission on the practicability of a hydro-electric power scheme. This report was not expected for some months, and thereafter the Commission must present its own report and recommendations to the two Governments.

Some Notes on Tunnelling Equipment

By ROLT HAMMOND, A.C.G.I., A.M.I.C.E. Particulars are given of the equipment used in a number of recent examples where high rates of advance have been achieved in tunnelling practice.

ROCK excavation is dependent upon efficient rock drills for its speedy execution, and in recent years there have been many interesting developments both in the drills themselves and the equipment used in conjunction with them. The pneumatic hammer drill is now the universal tool of the rock excavator, having almost entirely superseded the older type of piston machine.

There are three main groups of hammer drills, namely: the drifter or cradle-mounted drill, employed for drilling holes in all directions; the hand hammer drill, suitable for holes in the downward vertical direction or for holes not exceeding 35 degrees from the vertical, the heavier version being mounted on a tripod for quarry work; and, lastly, the stoper for all holes above 30 degrees from the horizontal. In each type there are heavy and light machines, according to the type of work and the class of rock being drilled. Heavy and robust machines are required for tough rocks, whereas in the softer rocks high drilling rates are achieved by light drills giving rapid blows.

The efficiency of a rock drill is determined by the fact that the drill best suited to the work is one which gives a blow of just sufficient force to chip the rock, because anything more than this does not achieve any further advance of the hole through the rock but merely pounds up the chips into still smaller fragments.

The rock drill deserves good maintenance if it is to give good service, and careful attention should be paid to adequate lubrication with a proper grade of oil, although lubrication with the wrong oil is better than no lubrication at all. There is no known precise method of hardening and tempering borer bits and shanks, because the processes have to be modified according to the different grades of steel used. In general, the aim should be to achieve the hardest possible cutting edge combined with the softest possible striking end on the shank, but the latter should be hard enough not to burr over under the repeated blows of the piston. The striking face of the shank should have a Sclerescope hardness of 55 or a Brinell hardness of 350, which will allow the shank to be filed; care should be taken to use a file which is in good condition, because a worn file is apt to give misleading results. This hardness is referable to the drill shank when first made and taken into use, because the constant hammering of the piston will cause a considerable extra hardness to develop.

The great point is to avoid having shanks which are too hard and which may cause damage to the piston. The shank is in use for only quite a short time, whereas the piston is striking a drill shank the whole time that it is operating, and is therefore running under much more severe conditions than the shank. One hard shank in a set of drills may do great damage to the point of the piston in a very short time. It is a great mistake to anneal periodically any part of the borer steel with a view to prolonging its life; when a steel breaks in use it is a sign that it has reached a safe limit of fatigue and no amount of annealing will remedy the defect.

The drill jumbo is now a standard piece of rock drilling equipment and is made in various sizes; some of the largest ever built were those used on the construction of the 50 ft. diameter diversion tunnels of the Boulder Dam project, and very large jumbos are at work now on the Kiewa scheme in Australia and an interesting recent development is the jumbo attachment fitted to the Eimco high speed loading shovel and shown in Fig. 1.

This rocker shovel has been specially developed for the high speed driving of tunnels, one of the most interesting examples of its application being the seven mile tunnel for the water supply of Baltimore. Five miles of this tunnel will have a diameter of seven feet, and two miles will be 10 feet in diameter. Working from six headings a maximum advance of 5,000 feet was achieved in one 30-day period. It is therefore obvious that when this rocker shovel can be combined with a drilling jumbo, the combination will be very effective in accelerating tunnel driving, because there will be no need to have any delay between mucking out one round and drilling the next.

The photograph shows how the horizontal support bar is mounted on the bucket. On each end there is a "stinger" operated by a compressed air piston, which bears against each side of the drift and holds the bar securely in place; no drill vibration is transmitted to the loader. By raising and lowering the bucket of the loader the drill bar can be set at any height within the range of operation. A special feature is the pair of safety chains provided to prevent movement of the bucket should the supply of compressed air fail; this arrangement also allows the loader to be moved with the bar clamped to the bucket and disconnected from the air. The chain is fastened from the rocker arm yoke to a bracket provided on the rear.

A further safety precaution is the pair of clamps mounted on the stinger arms, and locked in place butting against the bar after the bar is in place. This effectively prevents the stingers from retracting in the case of failure of air supply.

This jumbo takes about six minutes to set up, and

it is claimed to be able to meet a wide range of conditions within its capacity. The horizontal bar is available in different lengths, and the jumbo can be used with equal facility for drilling a pyramid vee cut or centre holes. The drill bar can be turned from straight front to a 30 degree angle on either side, the range of lengths for drifts varying from 6 to 17 ft.

An example of the high tunnelling speed which can be attained by means of the Eimco loader in conjunction with the suitable drilling equipment is provided by the Grootvlei haulageway on one of the Rand mines. In planning this work, the basis was assumed to be at least four 8 ft. rounds in a working day of 24 hours in a heading 12 ft. 6 in. wide by 10 ft. 10 in. high, or to achieve an advance of about 1,000 ft. per period of 26 working days. In February, 1948, the advance was 1,132 ft., equivalent to 138 rounds averaging 8.2 ft. per round. Average progress amounted to 43.5 ft. per day during that period.

After considerable trial and error, the drilling jumbo for this work was redesigned to meet the demands for high speed tunnelling. The Grootvlei jumbo weighed 2½ tons without the drilling equipment, which comprised six 3½ in. Leyner machines. A ring main of air and water pipes was provided on the upper deck. At the face, the jumbo was pushed into position by a locomotive and wooden wedges were placed at the back of each wheel, these sufficing to hold the jumbo in place during drilling.

The following drilling speeds were attained in shale, with and without the booster compressor. In the latter case the speed was 12.1 in. per minute when the air pressure was 72 lb. per sq. in. With the booster in operation, the speed was stepped up to 18.9 in. per minute and the air pressure to 95.6 lb. per sq. in. The Eimco Model 40 loader used on this work has a loading rate of from 3 to 4 tons of shattered rock per minute; about 1½ tons of debris could be loaded on the conveyor belt during the period when the mine cars were being changed.

The large drill jumbo is a heavy structural steel framework running on rails. One example, made by the Ingersoll Rand Company, has four working platforms with four drifter drills working at each level. An air hoist on the lowest of these three platforms powers a jib crane on the top deck that is used to operate a "cherry picker" muck-car switcher and to lift materials to the upper platforms.

An interesting insight into modern drilling technique using a large jumbo is provided by the Shipshaw power development in Canada, a sketch of the arrangement of drill holes and of the jumbo being shown in Fig. 2. Combined length of the six tunnels on this scheme was 2,560 ft., the breaking of a round of 11½ ft. requiring the drilling of 1,680 ft. of horizontal holes. In the diagram, we show the order of firing indicated by numbers, there being 140 holes in each round; depth of the vee-cut holes in the centre varied from 8 to 15 ft., the diameter of drill holes varying from 2 in. down to 1⅜ in. Each round pulled for a distance of 11 ft. 6 in. and it will be noted that in the invert of the tunnel there is a row of vertical holes.

There were 24 Canadian Ingersoll Rand No. 82 drifter drills mounted on this jumbo which moved forward on a caterpillar track; each drill was power-fed and worked at the rate of 23 ft. 4 in. per hour per drill. Drilling was done wet and the drilling time

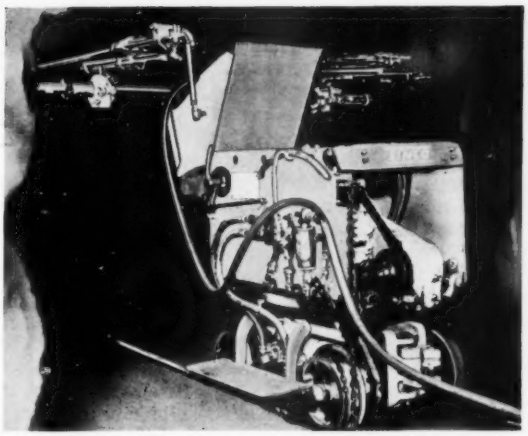


Fig. 1: Loading shovel fitted with jumbo attachment

per round was 3 hours. Loading and shooting time amounted to 1 hour 15 min., and the quantity of explosive used was 3.5 lb. of 60 per cent. gelignite per cubic yard of rock. After blasting, the shattered rock was loaded by a 1¾ cubic yard Marion electric shovel into tractor-drawn Athey wagons.

Some idea of the size of this job from the drilling angle is conveyed by the fact that 124 drifter and sinker drills, 38 wagon drills, and 98 hand held drills of the jackhammer type were employed, together with 39 well drills and several diamond drills. About 600,000 lb. of drill steel and 3,360,000 lb. of gelignite were consumed. The main compressor plant consisted of seven Canadian Ingersoll Rand synchronous motor-driven compressors with a combined capacity of 23,310 cu. ft. of free air per minute; a further 8,000 cu. ft. per minute was supplied by 16 portable and semi-portable units placed at convenient points. There were 33,400 ft. of compressed air mains, varying in diameter from 12 to 3 in., mainly with welded joints. Pressure in these mains was kept at 100 lb. per sq. in.

Drill steel was sharpened in a central plant, containing 13 oil-fired furnaces, 15 sharpeners and the necessary shank and bit punches, shank grinders and pedestal grinders. This shop handled 12,000 steels per day. More than two-thirds of the rock excavation on the entire project was in the cut in the upstream half of the canal. As the benches there were normally about 40 ft. high, a third lift was necessary in the central part where the maximum depth of cut was 105 feet. Most of the drilling on these benches was done with well drills, which were allocated to cuts exceeding 18 ft. deep and put in 6 in. dia. holes at intervals of 8 to 10 ft. Well drills also did some of the line drilling along the sides of the canal, the holes being spaced 3 to 5 feet apart; but most of this work was done with air-operated wagon drills working on 12 in. centres.

An interesting example of the use of diamond drilling was provided by the scheme adopted for blasting the tailrace plug, which served as a dam to keep the water out of most of the tailrace area during excavation (Fig. 3). This plug was 310 ft. long and contained 18,000 cubic yards of material. Before the shot was fired the tailrace area was flooded with water

to a depth of 15 feet to exert a cushioning effect against flying rock. The water level on the river side of the plug was 21 ft. 6 in. higher than in the tailrace, and this had a tendency to throw the rock into the latter. To receive it, a 40 foot wide section of the tailrace was excavated 10 feet below the final grade level. After the blast had been fired, soundings revealed that less than 500 cubic yards of material would have to be removed to reach the final grade.

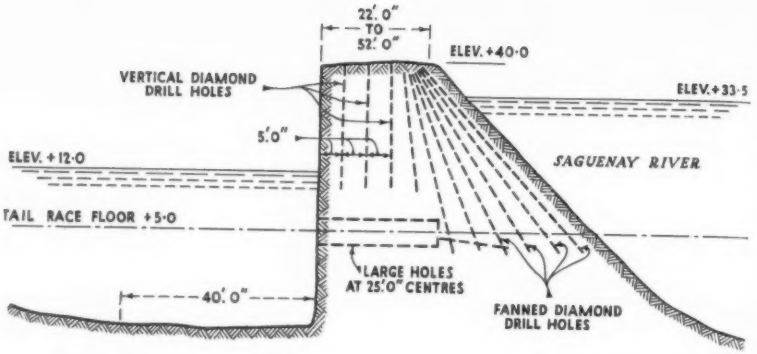


Fig. 3: Showing disposition of shotholes for blasting tail-race plug

Work now proceeding on the Kiewa project in Australia provides an excellent illustration of rock drilling on a large scale, as instanced by the headrace and tailrace tunnels of Plant. No. 4. The former is 12,000 feet long, has a cross section of 15 feet by 15 feet and is driven through grano-diorite. The tailrace is 16 feet wide, 20 feet high and more than two miles long. In the headrace tunnel drilling is done from a jumbo on which are mounted seven 3½ inch bore power-fed drifter drills, using detachable drill bits. The starting drills are 2 inches in diameter.

A drill round consists of about 80 holes, loaded with from 250 to 300 lbs. of gelignite. This charge breaks up about 65 cubic yards of material and represents an advance of about 8 feet. The broken debris is loaded by a Conway 75 shovel into side dump cars of 6 cubic yards capacity running on a 3 foot gauge track, shunting being done by means of a California switch which is moved forward as the heading advances. Haulage is by battery operated electric locomotives, and in the smaller tunnels Eimco rocker shovels are being substituted for the Conway loaders. The drill jumbos are also smaller.

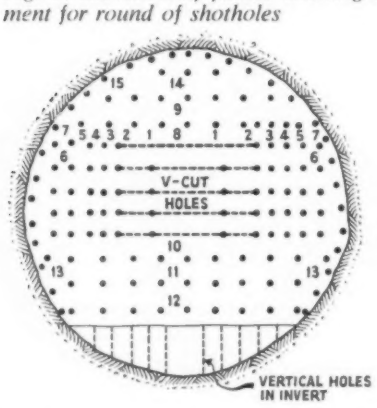
A further example of the high tunnelling speed which can be achieved by the use of an Eimco loader in combination with suitable drilling technique is afforded by the work carried out in driving the 6-mile Carlton Drainage Tunnel for the Golden Cycle Corporation of Colorado. This is driven through volcanic breccia and is 10 ft. wide and 11 ft. high; a steady rate of progress of 1,500 feet a month was maintained, the record for one day being 74 ft. and for a 31 day month 1,879 ft. A drill jumbo was used on the work, and the Eimco loader handled an average quantity of 34 cubic yards of shattered rock after each round was fired.

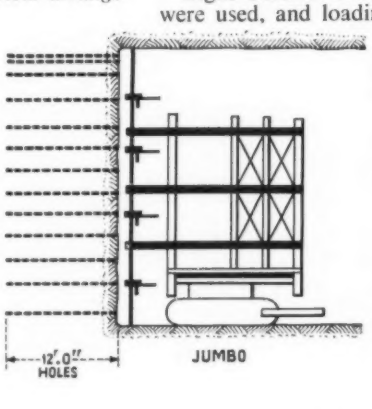
Another notable example of modern tunnelling is provided by the Delaware Aqueduct for the water supply of New York, work of a similar nature to this likely to be encountered on many water power developments. Fig. 5 shows a sketch of the "grasshopper" car passer used on this operation. This car had a drill jumbo mounted on its front end and was used on the portion of the aqueduct built by the Henry J. Kaiser Company, who drove and lined a length of 29,094 ft., driven from three shafts, respectively 480, 345 and 328 ft. deep. Air compressing plant included two Worthington compressors each driven by a 200 horse-power electric motor, three Ingersoll Rand compressors and one Gardner Denver compressor.

A typical drill round amounted to 79 holes, with cut holes having an average depth of 13 ft., the easers and trimmers being 11 ft. deep. The total charge consisted of between 500 and 600 lb. of Hercules Gelamite No. 1 explosive; this gave an average advance of about 9 ft., the average explosive consumption amounting to 3½ lb. per cubic yard. From 70 to 80 holes were drilled in a period of from 2 to 2½ hours, the total length of holes being 725 feet; this gave an average drilling speed of 31 ft. per hole per hour for each drill. Six instantaneous electric detonators and 73 delay electric detonators were used for exploding the charge.

Eight Gardner Denver automatic feed drifter drills were used, and loading of the shattered rock was a simple matter with the grasshopper device; empty mine cars were hauled up the back ramp and thence lowered to the mucking machine down the front ramp; after loading they were drawn out below the frame of the grasshopper. Average mucking time was 3½ hours and drilling took 2½ hours and such operations as loading and blasting, blowing out gas, setting drill steels and meal time amounted to about half an hour each.

Fig. 2: Elevation of jumbo showing typical arrangement for round of shotholes





The drilling crew consisted of a ganger, nine drill men, eleven spanner men, one motorman and one brakeman. The corresponding mucking crew consisted of a ganger, one machine operator, two miners, from six to eight labourers, two motormen and two brakemen. There were also two or three timbermen present during operations, steel supports for the ground being erected at a distance of about 30 ft. from the face. All this equipment is mentioned because the drilling apparatus is but one component of what is essentially an integrated whole.

One of the most interesting developments in drilling technique has been the evolution of the detachable drill bit, and much research in this country has been carried out by Holman Brothers, Ltd., of Camborne, who have developed the Holbit. There were many problems to be solved in the production of tungsten carbide drill bits to enable them to be used with advantage in any kind of rock. This firm carried out intensive experiments to discover the most suitable grade of tungsten carbide to use; the best shape for the tips, the most satisfactory method of securing them, the most appropriate heat treatment of the body, and the most effective method of attaching the body to the drill rod. Tests proved that the wear on this type of detachable bit amounted to about one-thousandth of an inch for every ten feet of hole drilled in Cornish granite. In order words, it is claimed that there is no appreciable difference in the rate of penetration as drilling proceeds, so that the hole is practically parallel.

A drill with a detachable bit may thus be used for drilling holes to depths of six or eight feet. When it is necessary to use two or more drill rods for a hole, as in drilling downwards with a hand-held machine, it is found that the difference in gauge between succeeding detachable bits is not nearly as great as with ordinary bits. Tests have proved that a Holbit will drill from 60 to 300 ft. or more, depending upon the nature of the rock, before redressing of the drill bit.

The introduction of the detachable bit can reasonably be described as a revolution in drilling technique. It enables higher average drilling speed to be maintained, eliminates the need for frequent changes of drill steels and reduces overall drilling time. Other very important advantages claimed are that smaller rock drills are used, with consequent reduction of air consumption; fewer drill rods are required and transport costs thereby reduced; and that drill sharpening is eliminated and blasting efficiency is increased.

Gold Coast Rivers

EXTENSIVE HYDRO-ELECTRIC SURVEY

A party of five engineers from the firm of Sir William Halcrow and Partners, consulting engineers, is now engaged at the request of the Gold Coast Government on a technical survey of the Volta River with a view to developing its resources for hydro-electric power, irrigation and navigation. The party includes Mr. E. V. Richards, B.Sc., M.Inst.C.E. (the leader), Mr. A. N. M. Robertson, B.A., M.Inst.C.E. (Irrigation), Mr. M. E. Bird, M.I.E.E., M.A.I.E.E., (Electrical), Mr. R. C. Taylor, B.Sc., assistant to the leader, and Mr. M. J. Portman, B.Sc., assistant to Mr. Robertson.

It was nearly a year ago that Mr. Peter A. Scott, also of the firm of Sir William Halcrow and Partners, paid a preliminary visit to the Gold Coast. After an initial survey of the Volta Basin he agreed with the Gold Coast Government the terms of reference, the composition of the investigating party, and the general plan of campaign. The terms of reference direct the consultants to recommend the best methods for the development of the resources. It will thus be their duty to ensure that the scheme adopted will develop all the power economically possible without adversely affecting other interests.

The survey will consider the prospects of hydro-electric power at Ajena and/or Bui, irrigation of lands in or near the Volta catchment, and provision of port facilities at either Ada or Accra. Methods of improving transport by developing a system of navigation on the lake to be formed by the proposed dam near Ajena (and by other means), and transport requirements resulting from the establishment of an aluminium factory are also be examined. Recommendations will be made as to what proportion of the power generated by any hydro-electric scheme would be devoted to aluminium production, and what proportion to other industries and towns.

The Volta, longest river in the Gold Coast, is a mile wide at Ada, where it flows into the sea. It is navigable by steam launches and lighters up to Akusi, the tidal limit. During the rainy season it is navigable as far as Senshi rapids, about five miles north of Kpong; but north of this point canoe traffic only is possible because of the rapids.

About 40 miles north-west of Yeji the Black and White Voltas join. The Black Volta comes in from French Senegal, while the White and Red Voltas rise in the country enclosed in the great bight of the Niger River south of Timbuctoo. These last two rivers join near Gambaga, and continue as the White Volta until that river joins the Black Volta at Yeji. The Voltas flow all the year, except at the very height of the dry season, and the rate varies from $2\frac{3}{4}$ miles an hour in the dry period to four miles an hour during the rains.

Obituary

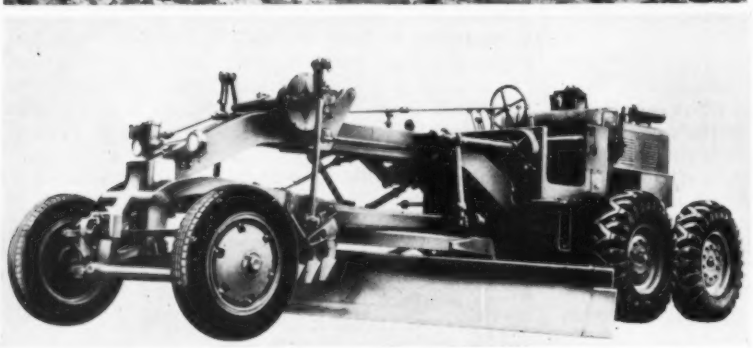
George von Schulthess, who died in November in his 52nd year, was unexpectedly taken out of a life of fullest activity. He received his engineering education at the Swiss Federal Institute of Technology, Zurich. After graduating in 1921 he joined the staff of the *Ateliers de Construction Oerlikon*, and for several years served in their branches in London, Paris and Milan. His noble personality was well received abroad and he contracted many lasting friendships. Returning to Zurich in 1928 he was engaged as a senior sales engineer at the main works, and in 1946 became assistant director of sales.

Herr von Schulthess was particularly interested in hydro-electric projects and was actively engaged in furthering their development, especially in the region of the Italo-Swiss border where he was able to negotiate agreements for the supply of electricity across the border and arrange projects to the mutual benefit of both sides. His many friends deeply regret his sudden passing.

Earth Moving Equipment

THE accompanying illustrations show respectively a self-propelled scraper and a grader that have been introduced by Blaw Knox Limited to augment their range of British-made land clearing and earth moving equipment. Both of these machines were demonstrated before a group of technologists recently at the Swanscombe quarries of the Associated Portland Cement Manufacturers Limited, where the chalk is overlain by a deposit of esturine sand some 20 ft. in thickness. This over-burden was being removed by the scraper and used for backfilling previous workings about one mile away. The Goliath scraper combines a two-wheeled tractor unit and a cable-operated open-top scraper which are coupled together by a restrained universal coupling to permit operation on the roughest of ground. The design enables this machine to cope with digging, loading, hauling, spreading and compacting operations, all of which are effected by conveniently arranged finger-tip controls. Power is provided by an A.E.C. direct-injection diesel engine developing 150 h.p. at 1,800 revs. per min., the lubricating system enabling the unit to operate continuously on gradients up to 45 deg. in any plane. A gear-box giving five forward speeds, ranging from 2½ to 20 miles per hour and a single reverse speed, is fitted. Power is transmitted through a 14 in. twin-plate air-operated clutch. From the gearbox a propeller shaft fitted with two flexible couplings transmits the drive to a spiral bevel reduction and to a differential gearbox embodying an air-operated lock, which is engaged when the machine is working under adverse conditions. Steering is power operated, affording sensitive and effortless manipulation. The welded open-top scraper permits rapid overhead loading when required and has a normal capacity of 12 cu. yards and a heaped capacity of 15 cu. yards. Accurate control of the scraper is assured by a double-drum power control unit which is shaft driven from the gearbox; air operation is provided. The 4-wheel brakes are likewise operated by air pressure, an independent transmission brake being provided for parking purposes. Such refinements as an air operated grease gun, air supply for tyre inflation and air jet cleaning are provided as standard. The dimensions of the Goliath, as will be gathered from our photograph, reduce the size of the driver to pigmy-like proportions, the overall width being 11 ft. and the length 35 ft. 10 in.; the weight is 19 tons. In spite of its great bulk the machine can be turned in a radius of 27 ft. and at the demonstration showed itself capable of carrying its load over a mile of the roughest of ground with the greatest of ease.

The new BK—12 motor grader which was keeping the haul-ways open is shown in the second picture and may be fitted either with a 6 cylinder engine developing 94 h.p. or a 4 cylinder engine developing 83 h.p. In either case the blade is 12 ft. and the gearcase gives six forward and two reverse speeds, the former ranging up to 20 miles per hour. High manœuvrability is assured by a turning radius of 35 ft. 8 in. and the blade and scarifier adjustments are ingeniously contrived to give a very precise blade position for every type of job. In spite of this flexibility it is impossible for the blade to be damaged by coming into contact with the wheels, frame or scarifier block. In ditching, bank cutting or other similar work, the front wheels can be angled up to 30 deg. to hold the grader to its work and prevent it from skidding out of line. This scraper has an overall length of 25 ft. 6 in. and weighs approximately 10 tons. All controls are power operated and the rear driving wheels are chain driven within a totally enclosed oil bath. At the Swanscombe quarries the grader was also demonstrated on bank cutting and scarifying operations and its effectiveness by common consent was beyond question.



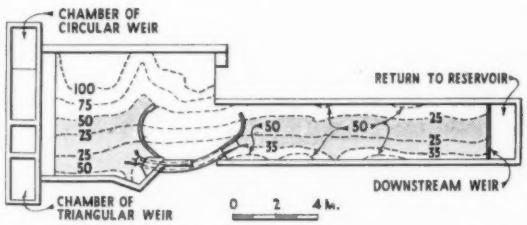
Top: Blaw Knox "Goliath Scraper"

Below: BK—12 Grader

From the Journals of the technical institutions and other material published in the Press of the World

Use of Model for Temporary Diversion

Among the water-power schemes now under consideration in Portugal, the Castelo do Bode dam is particularly interesting. Situated on the lower course of the Rio Zézère, a tributary of the Tagus, this reservoir would not only provide the country with an important source of hydro-electric energy but also enable the course of the river to be regulated, ensuring at the same time a large supply of irrigation water. As is the case in most Portuguese rivers, the flow of the Zézère varies between exceedingly low levels during the dry season and very high flood levels; in consideration of these wide fluctuations it was found necessary to set up a provisional diversion, carrying a flow of 2,000 m³/sec., so as to prevent the dam site from being flooded while work was in progress. After a brief survey of the problems to be solved the author emphasises the importance of tests on small-scale models with a view to reducing as far as possible losses of head at either end of the diversion.



Three possible solutions were investigated with the help of small-scale models. In the first and second project a tunnel 78.5 m² in cross-section was contemplated on either bank. The third project, which was subsequently adopted, comprised a single tunnel on the right bank with a cross-section of 99 m², and a slightly higher cofferdam on the upstream side.

The small-scale model (1 : 50), illustrated in the accompanying diagram, shows the course of the Zézère from a point 250 m upstream from the dam, and 760 m downstream, together with the diversion, and is fitted with the necessary measuring apparatus. The flow, which can be regulated according to requirements by a system of sluices, is measured previously to entering the model by means of a 90 deg. triangular weir. On the downstream side the level is automatically regulated in function of the flow by a discharge weir set once and for all so as to reproduce exactly the relation between the level and the flow of the river. The model thus works in accordance with Froude's law of similitude, and reproduces at the reduced scale the conditions of flow at the intake and outfall ends of the diversion.

Separate tests were carried out at the intake and outfall end. Those made at the intake end proved that the loss of head varied within the limits ascertained by preliminary calculations. On the basis of these tests an improved intake was designed in order to ensure a better admission of the water. At the outfall the tests led to the adoption of an uncommon method of energy dissipation, and enabled the outfall to be built in such a way as to meet thoroughly the local conditions.

In consideration of the torrential flow resulting from exceptionally high floods, an outfall with parallel sides would have caused the flow to slow down, and the level of the water would have been raised between the end of the gallery and the end of the outfall. The solution finally adopted consisted in widening gradually the outfall from its point of connection with the gallery and, at the same time, increasing the gradient of the counterslope.

Once the design of the actual outfall had been improved, the small-scale model still proved useful for investigating other problems, such as erosion and the stability of the downstream cofferdam, either at normal flow or in the case of floods. Finally, even while work was in progress, the model helped the contractor to adopt some refinement in the diversion works, and to achieve considerable saving of time and expenditure. The diversion was put into operation in August, 1947, and has since experienced a number of floods which in one case reached 1,900 m³/sec.; in this particular instance, the flow remained stabilised in the gallery at slightly over 1,500 m³/sec., while the peak of the flood was stored by the reservoir. A comparison of the photographs of both the model and the actual diversion, taken under similar conditions, show a striking similitude. (*J. Rueff, "La Houille Blanche," Vol. 4, No. 6, November-December 1949, p. 798, 12 pp., 21 ff.*).

Automatic Control of Turbines

D. Gaden, who discusses the influence of water-hammer on automatic speed control in hydraulic turbines, shows that the resulting difficulties are not entirely remedied by the existing systems of double control, and suggests that the formula he had previously submitted, viz.:

$$\tau' T > K \frac{3}{2} \Theta^2$$

should be adopted as expressing the conditions necessary to ensure the condition of stability of the regulation system.

In this formula:—

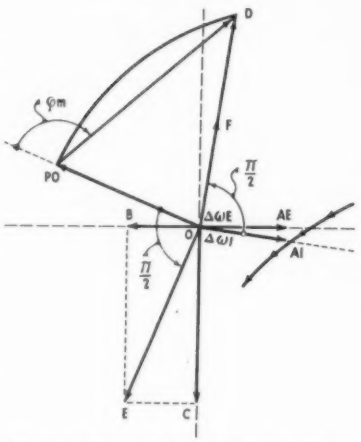
τ' is the time factor characterising the promptitude of regulation;

$$T = \frac{PD^2 \times n^2}{0.27\ N_0}\ 10^{-6}$$

is the time factor characterising the specific mechanical inertia of the set;

$$\Theta = \frac{\Sigma L V}{g H}$$

is the time factor characterising the specific hydraulic inertia of the water-supply system; and K a variable co-efficient.



View diagram showing effect of governing on change of pressure

By means of vector graphs based on the sinusoidal impulse method (Nyquist's criterium) the author explains the origin of the disturbing effect of water-hammer on the stability of regulation. With the help of further vector graphs he investigates the favourable influences, such as those tending to reduce the value of coefficient K—thus exerting a stabilising effect—which are due to the incidence of the difference of speed between the driving and opposing torque.

In his conclusion Gaden calls the electrical engineer to assist the water engineer in overcoming the influence of water-hammer on speed control in hydraulic turbines:—(i) by accepting the fact that within certain limits of frequency variation, the voltage regulator, instead of maintaining a constant voltage independently of frequency, causes the voltage to rise as frequency increases; (ii) by endeavouring to design a voltage regulator which will ensure an advance of the voltage fluctuation against the frequency fluctuation, and thus fulfil the requirements of automatic control. The accompanyink vector diagram shows the difference of effect with the difference in pressure on taking off load. (*D. Gaden, "La Houille Blanche," special issue B/1949, p. 717, 5 pp., 5 ff. A debate on this paper follows on p. 722.)*

Contractors' Notes

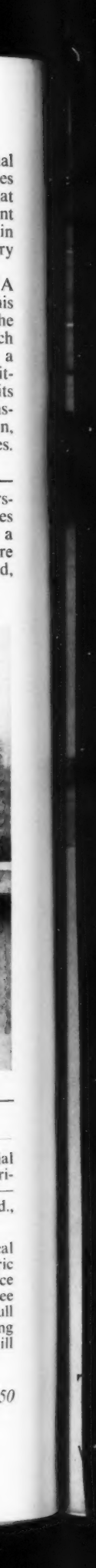
Hackbridge and Hewittic Electric Company. — The largest transformers completed in 1949 were two 60,000 kVA 125/66 kV, three-phase, water-cooled units with on-load tap changing equipment, shipped to Shawnigan Falls Power Station in Quebec, Canada and put into service in the autumn. With a weight of 111 tons each and an overall height, when installed, of 26 feet, these are among the largest transformers exported from Great Britain and are of special significance, in that they were for the dollar market, the value of the contract being then over a quarter of a million dollars.

Two 12,000 kVA 42/63/6.3 kV three-phase transformers despatched to Portugal for operation at the Seia Hydro-Electric Station of Empresa Hidro-Electrica da Serra da Estrela, presented unusual problems; restricted access and transport facilities making it necessary so to design the transformers that they could be dismantled down to the component cores and winding assemblies, with the tanks also in three sections, and quickly reassembled after delivery to site.

1949 has also seen the delivery of a 16,000 kVA 115/10.5 kV Hackbridge transformer to Finland, this unit having on-load tap changing equipment on the 115 kV side, of a type in which the selector switch mechanism is mounted above the transformer on a massive porcelain insulator, an arrangement permitting reduction of dimensions on high voltage units operating with a fully insulated neutral. This transformer, which is now installed at Oulu Power Station, will operate at exceptionally low winter temperatures.

The Thew Shovel Company, Lorain, Ohio.— Working on the top of the Allatoona Dam, Cartersville, Georgia, U.S. Army Corps of Engineers uses a Lorain MC 820, 45 ton Moto-Crane to lower a 29 ton gate into operating position. These gates are stored in reserve vaults and are lifted out as needed, carried into position and lowered by the Lorain.

CLASSIFIED ADVERTISEMENTS

WANTED—An experienced Geophysicist for managerial position. Applicants should give full details of experience, qualifications, and should state salary range. — Address Box No. 303, The E.C. Advertising Co. Ltd., 54, Old Broad Street, London, E.C.2.

BRITISH MANUFACTURER requires a good technical engineer with training and experience in Hydro Electric work including plant, and preferably with some practice in engineering contracts. Applicants must be of degree standard, age 25-35. Good prospects. Apply giving full details of experience and salary required, mentioning reference 764, to Box 700, *Water Power*, 33 Tothill Street, London, S.W.1.